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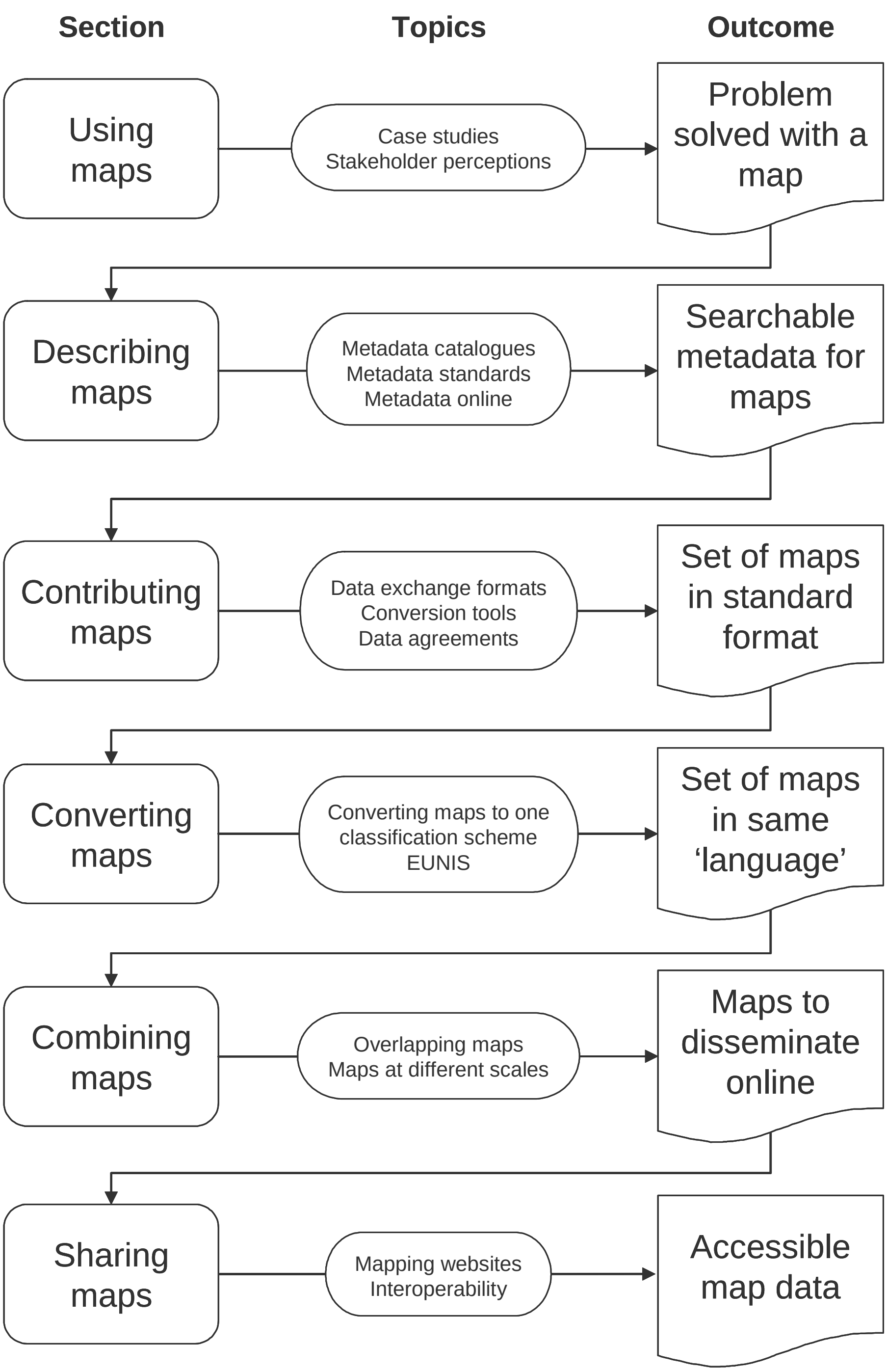
What can I do with my map?

Natalie Coltman

A habitat map is visual product that is the culmination of a complex process that involves the expert interpretation of data, designed to pass on specific message to the map user. This section addresses how messages from maps are used in environmental management – the purpose for which the maps were intended – as well as how maps can be used beyond their original purpose.



For many people, maps are pieces of art to be admired, but to others, they form an essential part of a toolset to solve complex problems in the natural environment. To further assist users in understanding the contribution that maps can make to environmental management, the first section describes some actual examples of how maps were used to solve practical problems, followed by a discussion of how users' perceptions of maps can affect how successfully the maps are exploited. In addition to the map product itself, details should be provided to describe the map and to help map users interpret the information shown on the map. The second section considers how maps can be described to others through the use of this kind of information, known as metadata, and to raise awareness in the marine habitat mapping community of the importance of metadata. Habitat maps are an extremely valuable resource and it is important that maximum value is extracted from each map since these maps are quite likely to be the *only* habitat maps for that area of seabed. Wherever possible, habitat maps should be made available to the wider scientific and marine management community to avoid an unnecessary duplication of effort to collect data in the same area. The section describing contributing data to other organisations provides guidance on the use of Data Exchange Formats, data processing and Data Agreements.

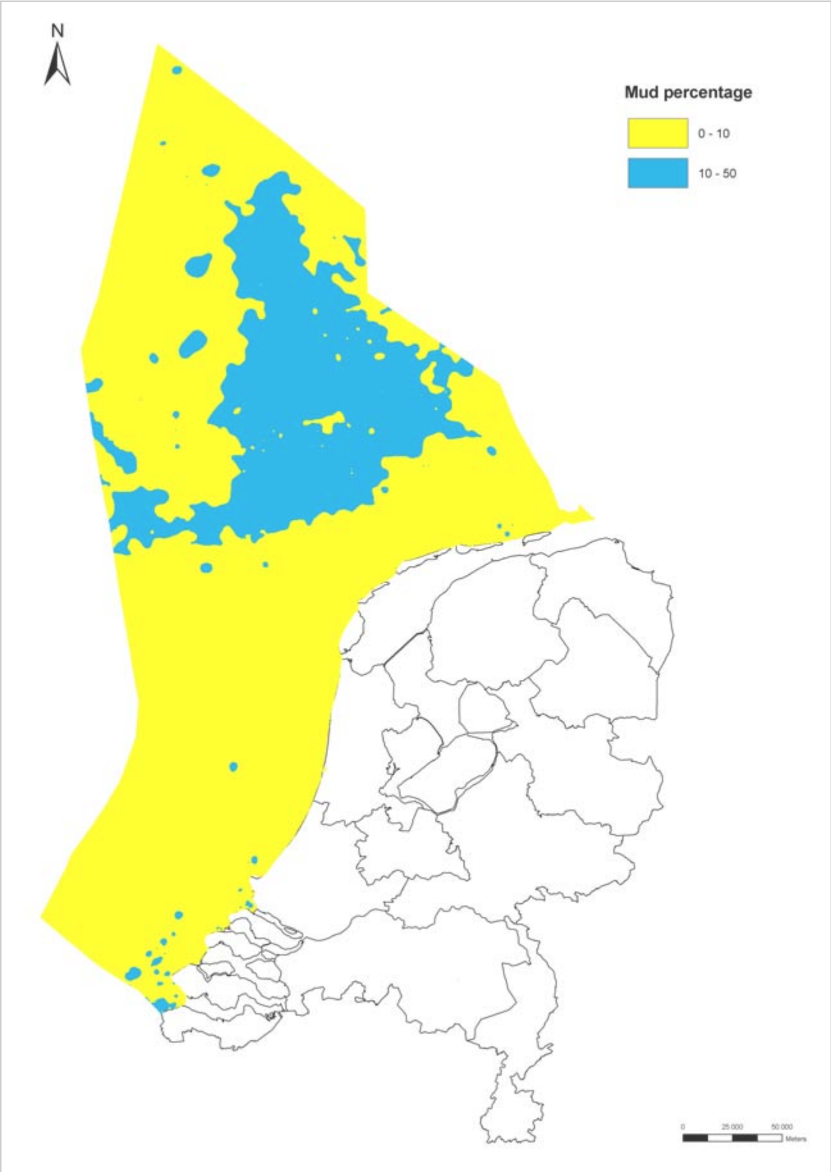
When marine habitat maps are made, mapping scientists chose mapping units which are best suited to the purpose of the map, perhaps to describe broadscale physical features or detailed biological information. The variety of reasons for mapping the seabed has resulted in an almost equal variety of mapping units used to make maps. In the context of marine habitat mapping we call these mapping units habitat classes. A defined set of habitat classes is known as a habitat classification scheme. The process of converting habitat classes from one classification to habitat classes in a second classification scheme has been called translation by the MESH Project. The fourth section will explain the benefits and feasibility of translation, and the processes by which it can be undertaken. When maps produced by individual habitat mapping studies are brought together, there are likely to be areas where maps overlap. Overlapping maps are not a problem as such; however, the maps have probably been produced at different scales for different purposes and using different methods. Even after translation to a common classification scheme, it is anticipated that maps will not always concur in areas of overlap. The fifth section gives advice about combining maps, specifically overlapping maps and maps produced for viewing at differing scales.

With the rapid development of computer technology over the past decade, the capability to rapidly access and process data and information has significantly changed our approach to marine environmental research and management. It is now possible to quickly search for information across multiple sources via the internet, often with the additional capability to download data (physically for local storage, or dynamically) for display and analysis on local machines. This final section describes how it is possible to make maps available on the internet, whether by contributing to an existing mapping website or by building a mapping website, and includes an outline of how to combine your maps with other online maps.

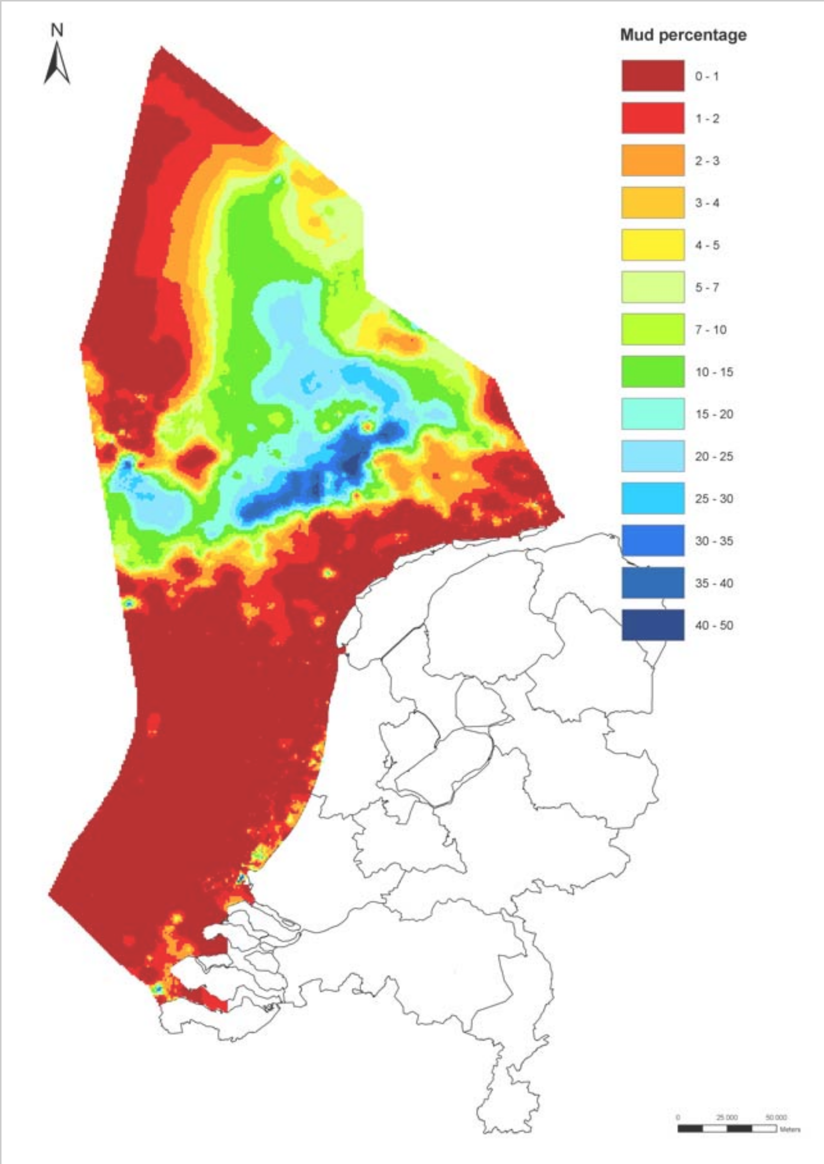
Using maps

Paul Gilliland & Sytze van Heteren

A habitat map is a visual product that is the culmination of a complex process that involves the expert interpretation of data. Maps are designed to pass on specific messages to the map user. To many, maps are pieces of art to be admired, but to others, they form an essential part of a toolset to solve complex problems in the natural environment. Unfortunately, these two extremes become somewhat blurred when users trying to solve problems do not have an understanding of maps beyond the concept of 'art'. Hopefully this Guide to habitat mapping will help improve users' understanding of habitat maps, in particular the limitations of maps, to escape the blurring of art and science. Remember that maps are *a* truth and not *the* truth: compare the maps of the Dutch continental shelf made for engineers and for biologists. Different map makers will produce differing maps of the same feature, unless they agree to use the same datasets and to follow the same protocols.



Traditional mud-percentage map made for stakeholders from the engineering community, using primarily visually estimated mud content.



Digitally produced mud-percentage map made for stakeholders from the biological community, using measured mud-content values.

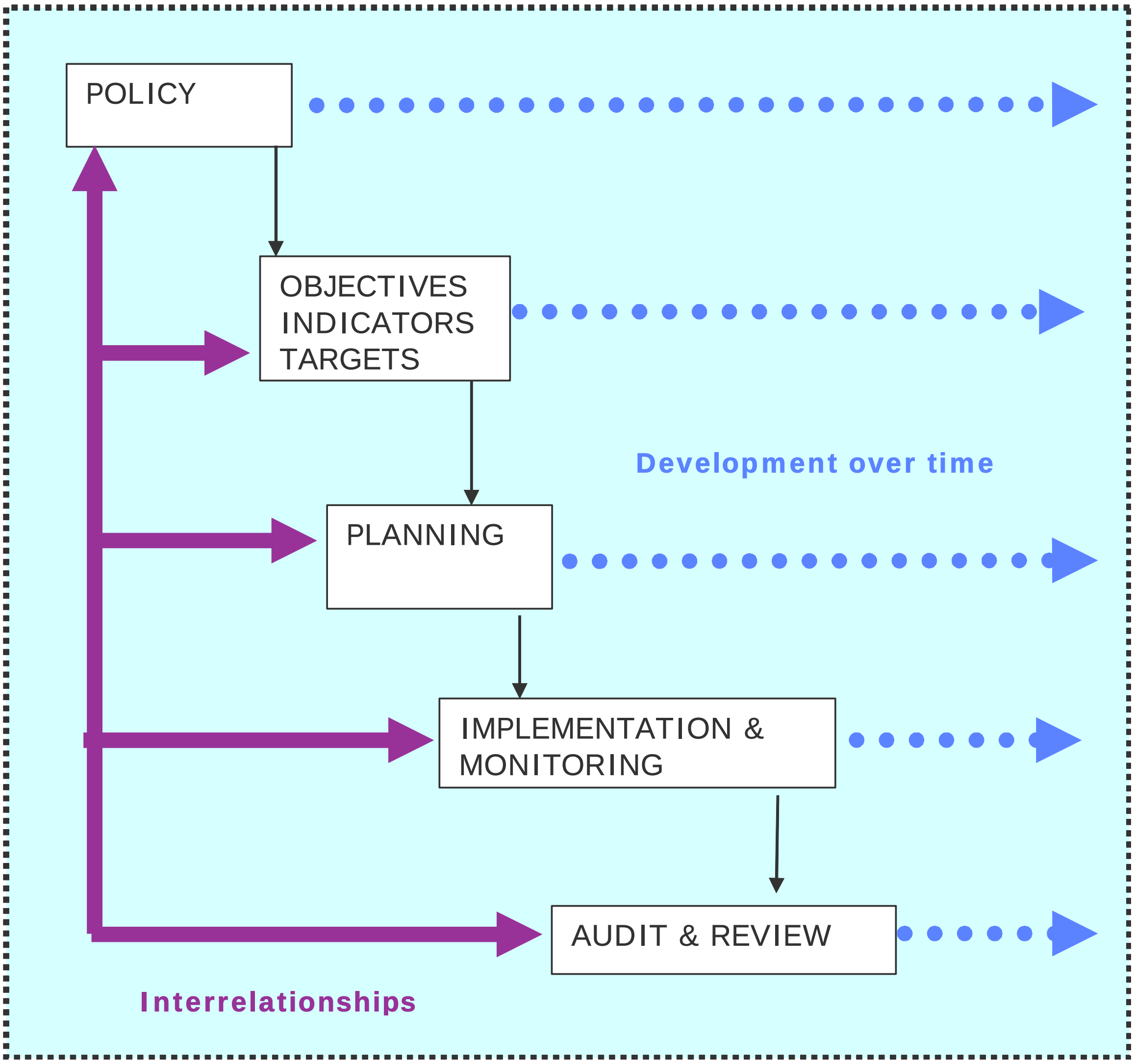
To further assist users in understanding the contribution that maps can make to environmental management, this section describes some actual examples of how maps were used to solve practical problems, followed by a discussion of how users' perceptions of maps can affect how successfully the maps are exploited. Seabed maps are a valuable resource because the data they are based upon are expensive to collect and time-consuming to interpret. This makes them relatively rare commodities; therefore it is vital that maximum value can be extracted from a data resource, both at the time of collection and into the future. This is addressed in the final part of section 6.1 entitled 'Making use of habitat maps beyond their original purpose'; this leads into the subsequent sections 6.2 to 6.6 which deal with stages in the life of a map beyond using it for the purpose for which it was originally intended.

Case studies on the use of habitat maps

There are many applications for seabed maps, from aiding safe navigation to identifying suitable fishing grounds. Increasingly the maps required for these diverse applications include habitat maps. Today, maps of habitat distribution are becoming invaluable in providing information for the sustainable management of a range of activities taking place in the marine environment and for the conservation and management of marine resources. The following are some of the foremost uses of marine habitat maps:

- To assist in making environmental assessments and hence decision-making regarding new developments, such as laying cables, building wind farms, extracting aggregates
- To facilitate strategic and spatial planning through knowledge of the distribution, extent and importance of habitats
- To inform on-going management of marine activities, such as fisheries, leisure activities
- To assess nature conservation value, including the assessment of habitat rarity in local, national and international contexts and identification of important biodiversity areas
- To map the sensitivity of areas to various human impacts, such as dredging or oil spills
- To help surveillance programmes in the assessment of the state of the seas, such as for national initiatives and regional seas conventions such as OSPAR and the Water Framework Directive
- To enable monitoring programmes to better target at a range of ecological features and potentially reduce monitoring effort through selection of sites based on better information
- To identify marine protected areas (MPAs) at both an individual and a network level, including selection of representative sites and management of sites after designation
- To increase our understanding of marine ecosystems, for example through study of relationships between seabed habitats, hydrodynamic conditions and fish communities

There are different ways to categorise the uses to which habitat maps are put. The key elements of environmental management shown in the diagram are used by many marine stakeholders to categorise their activities.



Key elements of environmental management

The main elements of this structure therefore form natural categories for the different applications of seabed habitat maps:

Policy → improved scientific understanding
Objectives → ecological quality objectives
Planning → resource identification
stakeholder participation
Implementation → resource management
conflict resolution
Monitoring → change in extent and quality of seabed habitats
Audit → sampling design
extraction and disposal sites
Review → effects of policy

A series of Case Studies were researched for the MESH UK Stakeholder Workshop (the full report is available on the MESH website [http://www.searchmesh.net/Default.aspx?page=1603]) to show a variety of uses for seabed habitat maps and how they can be instrumental in supporting decision-making on marine environmental matters. The uses of habitat maps included helping stakeholders visualise planning options, designing sampling strategies, providing a baseline record of the extent of particular habitats, and enabling long-term changes to be monitored and to communicating these changes to non-specialists. The Case Studies cover a range of geographic scales, from local to national. Mapping has also been valuable in providing a link between science and policy, and between specialists and other interested parties. In terms of the future use and development of MESH, the researched Case Studies highlight the MESH Project's potential value in providing a baseline with a harmonised classification scheme across a large geographic area. In all cases this would have meant that more time could have been spent on the main task rather than collating information to provide a foundation for the work.

Case Study 1: Sound of Arisaig candidate Special Area of Conservation - UK Marine SACs Project

The case study describes work to support the Sound of Arisaig (cSAC). A key source of information was the extent and distribution of the sandbank habitat (including maerl beds) for which the site was being designated. The habitat maps were presented to stakeholders and considered alongside other information such as on scallop dredging. This revealed a potential conflict and possibilities for zoning such activities in order that they might continue without damaging the maerl beds, for example no scallop dredging in <20m of water with a further 5m depth of water acting as a buffer zone.

Case Study 2: Eastern Channel Regional Environmental Assessment and monitoring for aggregates

The study concerns follow up work to a Regional Environmental Assessment of multiple aggregate dredging applications in the Eastern English Channel. A regional monitoring programme has been developed which includes habitat mapping as a principle component. A description of habitats and species across the region and a 'type' site were produced from a range of data, e.g. geophysical, camera/video. Monitoring is focussed on physical processes, e.g. sediment deposition, and biological communities, e.g. benthos. The collaborative approach taken has provided various benefits, including for habitat mapping, such as pooling of resources amongst individual developers, confidence in interpretation over varying spatial scales and providing a context in which to determine significance of operations.

Case Study 3: Assessment of human pressure on seabed features

A method is outlined for assessing the actual spatial footprint of a range of human activities to estimate their impacts expressed as different categories of pressure (e.g. siltation, obstruction, and extraction) using digital data for all major human activities operating in offshore waters. The outputs of this analysis are now being combined with the landscape types derived from UKSeaMap to provide an initial assessment of the presence or absence of pressure on particular seabed habitat types. The work indicates that geospatial data for human activities can be used to estimate pressure on marine landscapes. Understanding pressures applied to different landscapes could help, for example, in designing networks of marine protected areas and setting management objectives.

Case Study 4: A Marine Spatial Planning Scenario - Tidal Stream Energy

The case study describes part of a pilot study investigating Marine Spatial Planning in the Irish Sea. Scenarios were used to indicate how information might be used to make spatial allocations for certain future uses. Areas of potential tidal resource were overlain with other interests or sectoral uses which might occupy the same area of sea and/or form a conspicuous constraint to deploying tidal energy devices. One such interest was potential Natura 2000 sites based on habitat maps indicating presence of reefs or sandbanks. The 'policy' decision taken in this simulated scenario was that conflict between tidal energy and other spatially constrained interests would be avoided by the latter taking precedence.

Case Study 5: Using habitat maps for fisheries management

Habitat maps may be used by fisheries managers to map and quantify resources to direct fishing effort in order to develop more effective management regimes. More problematic for the same managers is the need to identify potential closed areas which may reduce the area available for fishing both on a spatial and a temporal basis. In the past the industry has regarded the use of habitat maps with suspicion regarding them simply as tool to restrict their activities. The adoption of a spatial planning approach in which habitat maps are a central tool has had only a patchy uptake by fisheries managers although there a some notable success in the shellfish sector. However, as the management of fisheries continues to move to an ecosystem management approach it is to be expected that habitat maps will play a central role in policy making. The fishing industry itself has long recognized the value of many of the techniques developed for habitat mapping and may well be regarded as a stimulus for the development of Acoustic Ground Discrimination Techniques. The shellfish aquaculture sector with its tradition of licensing areas of seabed has had a history of realizing the value of maps in managing their industry. The use of acoustic techniques for locating and quantifying resources has gained widespread acceptance in this sector.

Case Study 6: Sea Fisheries and the Flamborough Head European Marine Site

The case study describes work commissioned by the North Eastern Sea Fisheries (NESFC) to provide an ecological assessment (including habitat mapping) of the 3 established prohibited trawling areas within its jurisdiction and mapping of principle benthic habitats within the Flamborough Head SAC. A range of techniques were employed. The resulting information will enable comparison of structures within and outside the prohibited areas and to inform management of the SAC.

Case Study 7: Mapping seabed and water column features of UK seas - UKSeaMap

The case study describes work to use available geological, physical and hydrographical data, combined where possible with ecological information, to produce simple broadscale and ecologically relevant maps of the dominant seabed and water column features for the whole sea area under UK jurisdiction. The primary purpose of the maps is to provide a national and regional perspective on the distribution and extent of the UK's marine landscape types to support national and regional scale planning and management requirements. The outputs of UKSeaMap will provide an essential spatial information layer which, when combined with other environmental data, human activity information and regulatory information, will support more effective management of marine resources, improved interpretation of associated information, and assist implementation of national and international commitments and targets. These marine landscape maps are expected to help the UK Government and others deliver marine stewardship in the short to medium term, through better implementation of an ecosystem-based approach to management of the marine environment.

Understanding stakeholder perception of maps

In every map, a certain amount of detail is sacrificed to keep it legible at its intended scale. Ideally, map makers will highlight features that are of interest to potential map users, while leaving out features that are deemed less relevant. Also, a smart choice of class intervals and class assemblages will help stakeholders to recognize relevant spatial patterns. Very few maps are fit for all purposes; most maps should not be used by all stakeholders. Since maps are abstract representations, by their nature subjective, they must be interpreted carefully. A typical stakeholder, however, will not question the truthfulness of a map, particularly if it is all he or she has. When a map comes from a reputable organisation, it will almost automatically be considered to be true. This is the case even within the habitat mapping community, where biologists typically do not question the reliability of maps depicting physical parameters, and *vice versa*. The uniform GIS platform on which maps are made available invites non-expert end users to use and exchange maps for any purpose and to generate their own new maps without having to consult habitat specialists. The once obvious necessity to communicate with map makers is no longer felt.

With the advent of digital mapping, maps and grids are no longer static end products that cannot easily be updated or redrawn with different class intervals. A map can now be made in a time- and cost-efficient way for each research problem or policy decision, provided that the following conditions are met:

- All relevant data on physical and biological parameters are stored in one or more central databases that are easily accessible. Preferably, such databases are transnational and multidisciplinary.
- The associated metadata are available, enabling the selection of data subsets that meet requirements on issues such as quality, depth interval acquisition time, and adherence to specific standards and protocols.
- The end user provides information that can be used by the map maker to define classes, determine the appropriate scale, and visualize quantitative relationships between physical and biological parameters.

The new possibility to create multiple maps of a parameter or a set of parameters in a certain area may lead to confusion with the end users of maps. It will be difficult to select the most relevant map for a particular problem, and harder even to determine if the most useful existing map is good enough to answer your question or solve your dilemma. Without the security of having only one map available, marine habitat mappers need to create awareness with stakeholders that the possibility to choose between different maps of the same feature is a positive development, but that it is always best to consult the expert map maker to ensure an informed, optimal choice.

Making use of habitat maps beyond their original purpose

Habitat mapping is an expensive and time consuming process and therefore the final products – the habitat maps themselves – are extremely valuable resources. More importantly, these maps are quite likely to be the *only* habitat maps for that area of seabed since it is uncommon to find multiple maps for an area. Seabed habitat maps are generally the product of a study with specific objectives to tackle a practical problem, which might range from simply creating an inventory of seabed habitats for an area with no previous information, through to mapping the seabed to help site a structure or assess the impact of an anthropogenic activity. If you have followed through the advice for producing a habitat map described in this Guide, you will have a seabed habitat map that should help solve your practical problem. Examples of how maps have actually been used to help the management of anthropogenic activities are presented in the section Case studies on the use of habitat maps. As a valuable resource it is important that maximum value is extracted from each seabed habitat map. Wherever possible, habitat maps should be made available to the wider scientific and marine management community to avoid an unnecessary replication of effort. The following section offers some advice on data archiving to ensure maps are preserved for use in future studies. With the ever-expanding role of the internet in the dissemination of data and information, advertising the existence of habitat maps and ideally making the maps themselves available online are potentially important next steps once the maps have met their original function. Advice on how to make such additional uses of habitat maps is provided in this section.

Data archiving

Marine habitat mapping generates vast and valuable arrays of data that must be archived so that they can be accessed and used in the future. Too many data resources languish in desk drawers or on out dated hardware because of a lack of clear planning in projects about what will happen to the data beyond the life of the project. Together with a push for metadata to mobilise these hoards of seabed mapping data, there are national and international drives for improved access to information; for example, the EC Directive 2003/4/EC on public access to environmental information lays down requirements on public access to environmental information (http://europa.eu.int/eur-lex/pri/en/oj/dat/2003/l_041/l_04120030214en00260032.pdf). Efficient archiving is a key part of improving access to information. At the simplest level, creating appropriate metadata and identification numbers for data resources will help data management within an organisation. Operating across many sectors are national and international data archiving centres (DACs) which can remove some of the burdens of archiving from data owners (maintenance, dealing with requests), while their ownership is retained. In the UK the Marine Data and Information Partnership comprises public and private sector organisations working to provide harmonised stewardship and access to marine data and information, and so facilitate improved management of the seas around the UK.

Links to websites:

http://europa.eu.int/eur-lex/pri/en/oj/dat/2003/l_041/l_04120030214en00260032.pdf

http://www.oceannet.org/mdip/index.html

Describing maps

Maps are produced to convey information to other people. In addition to the map product itself, details should be provided to describe the map and to help map users interpret the information shown on the map. This section considers how maps can be described to others through the use of this kind of information, known as metadata, and to raise awareness in the marine habitat mapping community of the importance of metadata. A brief definition of metadata is given, followed by an explanation of why it is important to collect metadata. Next, the question of whether it is necessary to build a metadata catalogue is addressed, together with a decision process and an introduction to different levels of metadata. Deciding whether to develop a new metadata standard is then addressed, followed by guidance on how to build and populate a metadata catalogue. Finally, advice on how to share metadata with others is offered, particularly through online sources. Habitat mapping is an expensive and time consuming process and therefore the final products – the habitat maps themselves – are an extremely valuable resource. A useful and accurate description of the resource is almost as valuable as the resource itself, and hence metadata are an essential component of marine habitat mapping.

What are metadata?

Metadata are data about data, for example giving information about the characteristics and provenance of the data. Metadata answer questions you may have about a particular dataset: What type of data were collected? When? By whom? For what purpose? What methods were used? Perhaps most importantly, *where* were the data collected? This last component adds a spatial aspect to metadata, and is an essential part of the metadata needed to describe seabed mapping data.

Why collect metadata?

Seabed mapping data are a valuable resource because they are expensive to collect and time-consuming to interpret. This makes them relatively rare commodities; therefore it is vital that maximum value can be extracted from a data resource, both at the time of collection and into the future. Creating metadata for seabed mapping data maintains the value of the data for the organisation that collected them. This process prevents information about the data from being 'lost', if for example the original staff leave the organisation; undocumented data are often impossible to use, particularly if the data resource lacks a defined coordinate system or explanation of any codes used within the data resource. Furthermore, recording metadata at the time a dataset is created will save staff time in the future, especially if different staff need to carry out this task when they are not familiar with a resource. The existence of metadata can reduce time spent searching for data if the metadata are held centrally. Knowledge of existing seabed mapping data through accessible metadata records will help to avoid duplication of effort in collecting new data. This underpins the principle of collecting data once and using it many times.

Effective metadata collection can help government agencies comply with international or national directives relating to access of information. For example, the EC Directive 2003/4/EC on public access to environmental information lays down requirements on public access to environmental information, and the Aarhus Convention (http://www.unece.org/env/pp) establishes a number of rights of the public concerning the environment. The existing UK Environmental Information Regulations (EIRs) (http://www.defra.gov.uk/corporate/opengov/eir) have been updated accordingly to bring the UK into line with these international requirements.

International sharing of metadata is becoming increasingly important. Seabed features do not follow national boundaries, and contemporary measures at 'ecosystem management' consider regional seas rather than national waters. A project working in the North Sea may be interested in finding data collected by organisations based in several countries bordering the area. Metadata provide crucial information to better understand a data resource, and to help users locate appropriate data that meets their needs. Combining metadata records for individual data resources into a database can offer the user the opportunity to search and query the resulting metadata 'catalogue' in order to track down records which meet their needs. Such a catalogue can be distributed via the internet to create an online search tool.

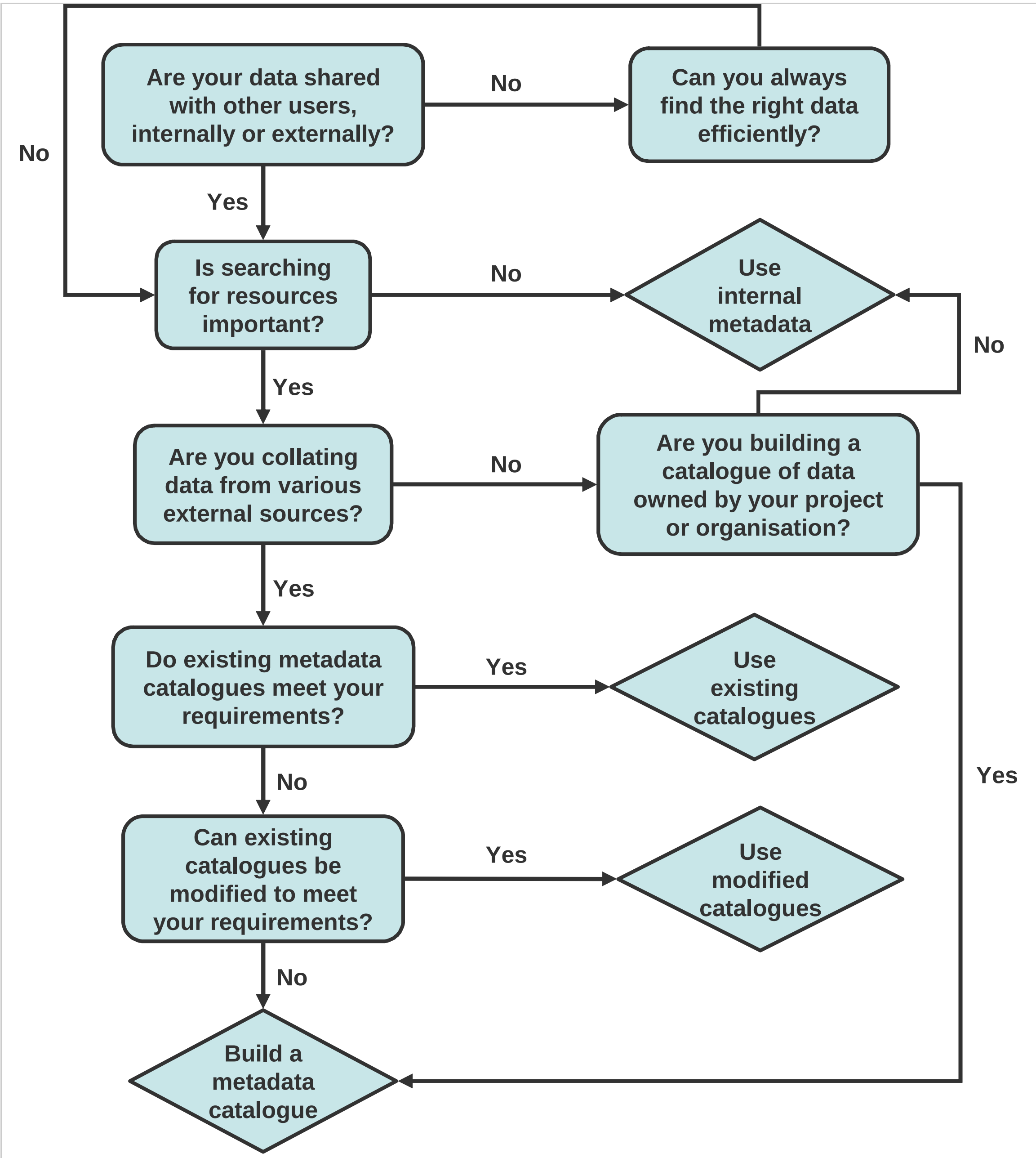
Do I need to build a metadata catalogue?

Metadata can be held in a searchable metadata catalogue (external) or stored with the resource itself (internal). Internal metadata are transferred with the data resources themselves and they are easily accessed by people using the data. ESRI ArcGIS™ software allows users to create internal metadata using the ArcCatalog™ application, which stores the information in an XML data file associated with the data resource; it is then possible to use ArcCatalog™ to search the text stored in metadata elements, although the search can be moderately slow. A disadvantage of using an internal set of metadata elements defined by a GIS package is that the metadata elements used must - by the nature of the wide range of users - be fairly generic elements often using broad divisions.

Decision process

Although it can be quite straightforward to use internal metadata because a system is already set up within your GIS software, external metadata may allow more efficient and flexible searching, such as through a database. Where external metadata are used, it is crucial to link the metadata to their data using unique identifiers. If you are considering building a metadata catalogue, the first question to ask yourself is whether your needs will be best served by using internal metadata or external metadata. A disadvantage of using only external metadata is that the data resources can be transferred without their associated metadata. An optimal solution may be the 'belt-and-braces' approach of internal and external metadata! It is also possible to develop tools which import internal metadata from the XML data files of multiple data resources, into a single database.

If you decide that using external metadata to catalogue your data resources will meet your needs, whether partly or fully, there may be existing metadata catalogues which already fulfil your requirements. For example, EU-SEASED (http://www.eu-seased.net) is a European project to improve access to information about the physical characteristics of the seabed. It is composed of three sub-projects: the European Marine Sediment Information Network (EUMARSIN), who have developed a marine sediment metadatabase; EUROCORE who contribute metadata for seabed cores the database developed by EUMARSIN; the EUROSEISMIC project has developed a searchable catalogue of marine seismic and sonar survey data held at European institutions. Metadata contributed by all three projects are available through the EU-SEASED website (http://www.eu-seased.net) above. Spend time investigating whether the type of data that most interests you are already listed in a metadata catalogue. You may find that it is possible to modify an existing metadata catalogue to meet your needs rather than to build a new catalogue. If you want to catalogue resources solely owned by your project or organisation, it is unlikely that a suitable catalogue will already exist. This decision process is shown in the flow chart “Do you need to build a metadata catalogue?". Remember that designing and building a catalogue may be less time-consuming than actually populating it with your metadata records! Using this decision process the MESH Project decided to build an external metadata catalogue. Full details of the catalogue are given in the document The *MESH Online Metadata Catalogue.doc* in the *Resources* section of the MESH Guide.



Do you need to build a metadata catalogue?

Metadata levels

There are different types of metadata record whose content will vary according to the 'level' of metadata. At the simplest level there are what are commonly termed Discovery metadata: these should provide the necessary information to describe the data sufficiently to enable the user to find the data of interest (i.e. to answer the who? what? where? and when? questions). A point of contact for further information should also be included at this level. Beyond discovery metadata, different names are often used depending on the metadata 'model' being followed. The second level is often referred to as exploration metadata: these should help the user to decide whether the data are suitable for the intended purpose, for example are the data suitable for a planned analysis? At the lowest, most detailed level are the metadata which are essential for obtaining and using the data. A useful analogy is the labelling on food packets. The information on the front of the packet could be likened to *discovery metadata*: the product name and brand, as well as what the consumer can expect it to taste like! The customer has to read the packet in more detail to obtain the *exploration metadata*, such as the ingredients list and quantity contained in the packet. Finally, the directions for use and 'use by' date would be equivalent to the *exploitation metadata*. It is clear that depending of the purpose of your metadata catalogue, the level of metadata used will vary.

Do I need to develop a new metadata standard?

There is an extremely wide range of information that could be recorded to describe a data resource; the choice of which information to include in your metadata catalogue can be overwhelming! However, metadata standards are available which describe the pieces of information that should be recorded about a data resource, and how they should be recorded. The individual pieces of information in a metadata standard are called metadata elements; for example, the title of a resource is a metadata element that can be recorded as a text field of up to 255 characters. When organisations use the same metadata standard, there is consistency for users to compare data resources. It also simplifies the sharing of metadata between projects or organisations. Metadata standards can be international or national, or internal to an organisation or project.

For example, the International Organization for Standardization (http;//www.iso.org) has defined a metadata standard for describing digital geographic data (ISO 19115, 2003). Gigateway (http://www.gigateway.org.uk) offers assistance and guidance on the collection of metadata to national and international standards as well as purpose built software to create metadata. Gigateway is a discovery metadata service operated by the Association for Geographic Information (AGI) on behalf of the UK's Department for Communities and Local Government (DCLG) under the National Interest Mapping Agreement (NIMSA). This is a defined element set for describing geo-spatial, discovery level metadata within the United Kingdom. Metadata services are also used within organisations as part of their internal data management systems.

When developing a metadata standard for your use, you should consider whether existing standards are fit for your purpose. As mentioned above for metadata catalogues, the existing standards could be modified to be more useful to you. For example, using metadata elements from a published standard but with modified names might help you to match the elements to an existing internal data management system. Developing a new metadata standard will take time, particularly if the standard is for use across several organisations who must agree on the metadata elements. The result may be that your metadata elements do not map to (match) elements in existing standards. This may not be a problem at this time within your organisation or project, but in the future if the metadata are contributed to national or international programmes, compatibility will be an important issue. Wherever possible, you should adopt existing metadata standards or, if developing your own, use standard (defined) metadata elements before defining any new elements. The metadata standard used by MESH is described in the document *The MESH Metadata guidance.doc*; the template spreadsheets required are the *MESH Metadata template.xls* and the *MESH Contacts database template.xls*. All files are available in the *Resources* section of the MESH Guide.

How do I build and populate my metadata catalogue?

Once you have selected a metadata standard, the process of designing, building and populating a metadata catalogue will vary significantly depending on the purpose of the catalogue. The following text offers some basic advice to someone faced with building and populating a metadata catalogue, based on our experience in the MESH Project. It is divided into 'Dos' and 'Do nots'. Full details of how MESH built and populated their metadata catalogue can be found in the document *The MESH Online Metadata Catalogue.doc* in the *Resources* section of the MESH Guide.

Remember to:

- Include mandatory and optional metadata elements. Mandatory elements ensure that the metadata record meets the minimum standard to provide useful information (ideally the basic 'Discovery metadata' elements of who, what, where, and when questions). Optional elements give flexibility because certain metadata elements may not be relevant to a particular type of data.
- Add metadata elements to existing metadata standards. This can assist organisations or projects to link their metadata catalogue to an internal data management system. For example internal library codes for documents in which the data were published.
- Include metadata elements that can be used to assess the confidence a user has in a map. For users of seabed habitat maps it is important to know how 'good' a map is in relation to their needs. This is called confidence: a statement about how reliable a map user thinks the map is given its purpose. (see 'The MESH Approach to Confidence Assessment' in *How Good Is My Map?*)
- Carefully control the values entered into metadata records: this increases the value of the metadata and helps to reduce problems with searching the metadata catalogue. This could be achieved simply through using of data entry forms for direct creation of metadata records into a database. Alternatively, spreadsheet templates containing metadata elements can be automatically validated as they are imported. The latter system works well if there are many metadata providers in different organisations supplying metadata records to a central database. However, if there is a single person or organisation who is the originator of the metadata, direct data entry to the database through forms is often the best solution.

- Design your metadata catalogue so that it can be made available online. This will encourage data providers to submit metadata in order to promote their resources.
- Design a catalogue containing the correct level of detail. Including sufficient information so that a search of the catalogue will return the results that the users require, but not so much that they are overwhelmed by too many returns or too much information for each record.

Remember not to:

- Try to include *all* elements from an existing metadata standard if they do not meet your requirements and will be an unnecessary burden to populate and maintain. Remember that the users of the catalogue must be able to interpret the metadata they receive from a search to judge whether a resource is of interest. Equally, do not feel that you cannot add elements to those in an existing standard if this creates a more valuable catalogue for your purposes.
- Assume that manually entered metadata entries will be free from errors: be sure to validate entries.
- Use too many metadata elements which require free text entry of information. Controlling entries helps but some free text entry will always be necessary and typing mistakes may cause problems. This makes searching the catalogue more difficult because the same entry can be written in several formats. For example “British National Grid” or “BNG” or “B.N.G.” Instead, try to include elements which have a defined element domain [link to glossary]: an element domain is the range of allowable values for that element, for example a set list of terms.
- Spend time copying entries from existing metadata catalogues into your catalogue! Metadata records can be shared between separate catalogues using technical solutions. For more information see the section ‘How can I share my metadata with others?’.
- Build a catalogue which is not easily searchable by others without detailed knowledge of the cataloguing system. This can be avoided by building search forms in the database or by offering search tools on an intranet or internet site.

How can I share my metadata with others?

After spending time and money to build and populate a metadata catalogue, it is a resource that should be shared with others wherever if possible. A metadata catalogue that has an internal data management purpose could be shared with users in that organisation by searching the database over a network or an intranet. However, this will not be available to users outside the organisation. The audience of the catalogue can be widened by making the database downloadable from a website, or by implementing online search facilities so that users are always searching the most up-to-date version of the database.

Links can be established between separate online metadata catalogues to offer users a wider source of information. These sources can range from simple hyperlinks to make users aware of other catalogues, to applications which allow metadata records to be shared between online metadata catalogues. In this way a search of one online metadata catalogue can return records held by a separate catalogue. This capability of systems to exchange metadata is part of a wider concept of interoperability; interoperability is defined as the capability to communicate, execute programs, or transfer data among various functional units in a manner that requires the user to have little or no knowledge of the unique characteristics of those units[1]. Sharing MESH metadata is described in the document *The MESH Online Metadata Catalogue*.*doc* available in the *Resources* section of the MESH Guide.

OceanNET (http://www.oceannet.org) is a site hosting three UK working groups: the UK Marine Environmental Network, MED; the Marine Environmental Data and Information Partnership

MDIP (http://www.oceannet.org/mdip/index.html) and the UK Global Ocean Observing System Action Group (GOOSAG). Of these working groups, the UK MED network provides access to many UK and European marine metadata catalogues, as well as links to metadata catalogues outside the network. This site is an informative starting point to identify marine metadata catalogues in Europe and the UK to which you may wish to contribute metadata. The following paragraphs provide brief descriptions of some of the catalogues available which may be of particular interest to the European seabed habitat mapping community.

The National Biodiversity Network Gateway (http//:www.searchNBN.net) allows you to view distribution maps and download UK wildlife data by using a variety of interactive tools. A set of metadata elements for each dataset can be accessed on the site.

Integrated Coastal Hydrography (http//:www.coastalhydrography.com) is a partnership between the United Kingdom Hydrographic Office (UKHO), the Environment Agency, Ordnance Survey and the Maritime and Coastguard Agency (MCA). The project has created an on-line metadatabase containing hydrographic metadata relating to studies in the shallow coastal waters around the UK coast.

The Marine Irish Digital Atlas (http://mida.ucc.ie) is an online resource for coastal and marine information and spatial data in Ireland. The data fall into four main categories: management, physical environment, biological environment and socio-economic activity. The website includes a searchable metadata catalogue which applies the ISO 19115 metadata standard, and an interactive atlas which allows the user to view and query layers owned by various organisations.

MAGIC (http://www.magic.gov.uk) is a partnership project involving six UK government organisations. The project website contains a web-based interactive map to bring together information on key environmental schemes and designations in one place. The project collaborators commissioned the Coastal and Marine Resource Atlas, which contains environmental and other resource datasets covering the Great Britain coastline and marine areas of the UK Continental Shelf. The Atlas is designed as a web based tool accessible through the MAGIC website, which provides a wide range of information on coastal and marine resources. Again, each dataset in the atlas has an associated metadata record which can also be retrieved on the website.

[1] Proposed Draft Technical Report for: ISO/IEC xxxxx, Information technology - Learning, education, and training - Management and delivery - Specification and use of extensions and profiles. [http://jtc1sc36.org/doc/36N0646.pdf]

Links to websites:

http://www.unece.org/env/pp

http://www.defra.gov.uk/corporate/opengov/eir

http://www.eu-seased.net/

http://www.iso.org/

http://www.gigateway.org.uk/

http://www.oceannet.org/

http://www.oceannet.org/mdip/index.html

http://www.searchnbn.net/

http://www.hydrographicsociety.org/

http://mida.ucc.ie

http://www.magic.gov.uk

Contributing maps

As habitat maps are an extremely valuable resource, it is important that maximum value is extracted from each map since they are likely to be the *only* habitat maps for that area of seabed. Wherever possible, habitat maps should be made available to the wider scientific and marine management community to avoid an unnecessary duplication of effort to collect data in the same area. The argument in support of contributing to others is put forward, followed by a discussion of issues to consider when transferring data between organisations. This section describes the use of data exchange formats, data conversion to standard formats, and the benefits of data agreements. The MESH Project has defined Data Exchange Formats and has developed tools for cleaning and formatting ESRI™ shapefiles. Gathering together existing data in this way plays a vital role in the habitat mapping process: the data collated may contribute to each of the main steps from the initial planning (e.g. to determine whether new data are required), to map production (e.g. by providing additional data layers for analysis) and interpretation of the results (e.g. by setting local results in a wider geographic context).

Why contribute data?

Marine habitat mapping data are an extremely valuable resource, largely as a consequence of the cost of collection, processing and interpretation, and thus it is vital that they are maintained in a suitable form to ensure maximum value are extracted. Appropriate and efficient data archiving is a fundamental element to expedite the process of contributing your data to other projects or organisations data archiving. *Data collation* is the term used for gathering together existing data resources both from within an organisation and from external sources. It is used in preference to *data collection*, which generally implies the creation of new data (such as from field surveys). In theory, the data collation process is simple, comprising four steps: locate the data resource, retrieve/obtain the data resource, process (convert) the data resource to meet your requirements and, disseminate the data resource in its collated format. Unfortunately in practice, data collation would more commonly appear to be a very tortuous process because data resources are often poorly described and badly archived.

The consideration of a data request and supplying the data can impose a significant time burden on individuals and organisations. Often this burden if further complicated if the data resources are not easily retrieved from archives because there is no internal data management system. Other typical difficulties encountered are:

- The data resources predate the time when storing of electronic data became commonplace.
- There may be fears that the Intellectual Property Rights (IPR) of the data resource will be lost by sharing the electronic data with another organisation.
- A misunderstanding arises to the purpose for which the data resources are being collated, which may compound these fears over loss of IPR.
- Data resources may be stored in electronic formats which are no longer accessible by the contemporary technologies employed by many organisations.

However, converting data to useable formats for wider dissemination can be strong motivation for contributing data. For example, data providers may gain benefit from promoting their data online by simply supplying their products to other projects, when they do not have resources available to set up their own web mapping systems. Any data collation process should be carefully considered and ideally, the likelihood of success for each step should be investigated before embarking on the process. Experience dictates that the time required is often many times longer than the original estimate.

How do I contribute my data?

Even the apparently specific term ‘seabed habitat mapping data’ actually covers a very large range of types and format of data. As seabed mapping technology advances, manufacturers modify the structure and format of the raw data, and similar changes occur with the data formats of the GIS mapping software used to analyse these data and create the final maps. Consequently, one might find that the format of data resources encountered during a data collection project is nearly infinite!! To overcome such difficulties, data recipients need to carefully define what type of data they actually require, and describe a format that will easily integrate with other data collated; these definitions are set out in a Data Exchange Format. Data owners or data suppliers can then determine if they are able to meet this requirement and determine whether they are easily able to convert their data, or whether they have to supply the data in its native format and leave the data conversion to the organisation undertaking the data collation project. Data conversion and re-formatting is potentially a very time consuming process and before embarking on such a venture careful consideration must be given to the likely cost and perceived benefit of the results. Seabed mapping data resources are valuable commodities and data owners generally wish to extract maximum benefit from their investment. Organisations collating data will be receiving these resources at a fraction of their original cost. Data owners and data recipients need to establish a common understanding on the quality of data and the terms for the use and dissemination that respect the value of the data resource. Such an understanding may be set out in a data agreement between the owner and recipient.

Data exchange formats

Data Exchange Formats (DEFs) define the characteristics of data to be exchanged between parties. DEFs facilitate the exchange of seabed mapping data between individuals, projects or organisations by clearly stating the recipient’s requirement. It may not always be practical to receive data from data providers in this format because it will take a data provider time to convert data into a particular format. However, even if resources are not available to convert data to a DEF, it still good practice for data providers to find out the DEF so that they are aware of the format to which any data they provide will be converted. In the context of seabed mapping data, a DEF can refer to either vector (points, polygons or lines) or raster data resources. At the simplest level, a DEF should:

- State the file formats expected. For example, CSV (comma separated values) is a common text file format, an ESRI™ shapefile for GIS vector data, or JPEG or TIFF for raster or image data;
- Stipulate a coordinate system;

- Define the required attribute(s).

Most additional DEF specifications are only relevant to vector data resources. These specifications concern the multiple attributes which can be present in vector format data, whereas raster data have a single attribute for each pixel. The name and format of attributes which should be associated with features in the data resource are specified. Two of the main attributes in a data resource should be identifiers (keys): the file identifier and the feature identifier. Together these will provide a unique key for any feature out of a set of features taken from many different data resources. This is essential to maintain an audit trail for each feature in the vector dataset, since the internal identifiers generated by GIS (geographic information systems) software are often overwritten when files are merged or otherwise manipulated using GIS.

The MESH Data Exchange Formats define data exchange formats for different data types, for example DEFs for habitat maps and a DEF for benthic sample data. The MESH Original Habitat DEF shown here is a DEF for habitat maps, and is an example of how this information can be conveyed to users, taken from the set of MESH DEFs. An example attribute table is shown which belongs to a polygon shapefile after conversion to the MESH Original Habitat DEF.

MESH Original Habitat DEF		
Field name	**Data type (length)**	**Description**
FID	Number	Feature ID. Internally generated identification number for each polygon (not visible if .dbf file is opened using MS Excel).
Shape	Text (8)	Internally generated text, indicating whether the feature is a polygon, point or line (not visible if .dbf file is opened using MS Excel). This will be 'POLYGON' in the Original Habitat DEF.
POLYGON	Long integer (Precision 8)	Identification number for each polygon which must be manually created as ascending integers 1,2,3… etc. **Do not use the value 0, as this can cause errors on the MESH webGIS**. This label for each polygon is necessary to identify the original polygon because the *FID* field may change during the processing of datasets.
GUI	Text (8)	Globally unique identifier (GUI) of the habitat map. Consists of 2 letter country code (which corresponds to ISO3166-1) plus 6 digits. For example, a dataset from the United Kingdom would be written GB000005. Each GUI must correspond to a record in the **metadata catalogue**. A metadata template can be downloaded from the MESH website, www.searchmesh.net.

MESH Original Habitat DEF		
Field name	**Data type (length)**	**Description**
ORIG_HAB	Text (255)	The information identifying the habitat type present in a polygon, either a code or text (the description of the habitat).

The attribute names, formats, lengths (in brackets) and descriptions for the MESH Original Habitat DEF.

FID	Shape	POLYGON	GUI	ORIG_HAB
0	Polygon	1	GB000253	Ldig.Ldig
1	Polygon	2	GB000253	Fser.Fser
2	Polygon	3	GB000253	BarSh
3	Polygon	4	GB000253	Asc.Asc
4	Polygon	5	GB000253	Asc.Asc
5	Polygon	6	GB000253	Pel/Fspi
6	Polygon	7	GB000253	Asc.Asc
7	Polygon	8	GB000253	BarSh
8	Polygon	9	GB000253	YG/Ver
9	Polygon	10	GB000253	Him
10	Polygon	11	GB000253	BPat.Fvesl

An example attribute table belonging to a polygon shapefile after conversion to the MESH Original Habitat DEF. The shapefile contains 11 features, with each row in the table corresponding to a single feature (polygon in this case).

Raster data have a single attribute for each pixel and hence these specifications are not necessary in DEFs for raster data. Vector data will be considered in more detail here because they are largely used by the seabed mapping community to visualise and share the final results of seabed surveys. Formatting attribute data to comply with a DEF can be a time consuming process. Changes usually apply at the level of whole attributes rather than attribute values for a particular feature, for example adding and deleting attributes, or editing attribute names.

Editing attribute names in particular may cause problems if it is important to keep the attributes in a particular *sequence*. The DEFs used in MESH also stipulate the left-to-right sequence of attributes in the attribute table to comply with functionality used by the MESH webGIS. This sequence can be seen in Table 2; it is essential that POLYGON, GUI and ORIG_HAB appear in this order. In ESRI™ packages commonly in use, it is not possible to insert an attribute or edit the name of existing attributes. Furthermore, because of the strict sequence, if you discover an error in the name of the *first* attribute 'POLYGON', the error cannot simply be corrected by adding a new attribute with the correct name to the right of the last attribute (ORIB_HAB) in the table, and removing the existing attribute (after copying across the data). Instead, this change involves data manipulation to retain the sequence of attributes in the attribute table. The amount of data manipulation increases as the number of attributes increases.

Further data processing

Processing data so that it complies with standard formats can be very time-consuming but is an essential part of making your data resources accessible to others within and beyond your organisation. The two most common GIS software used for seabed mapping data in Europe are ESRI™'s suite of GIS software products, today referred to as *ArcGIS*™, and MapInfo Corporation's *MapInfo Professional*™. Files produced by either of these two packages can be readily converted to the format used in the other. Generally it is also possible to convert file formats from alternative software for use in ArcGIS™ or MapInfo Professional™. MESH chose the ESRI™ shapefile as its standard format, principally because the ArcGIS™ product was used by the majority of the project partnership.

After conversion of data resources to the chosen file format, the other characteristics of the data resources that need to be standardised are the spatial reference system and the data attributes. This process can be expedited by using various tools to convert batches of files automatically, or to check formats of collated data resources. Many of these tools are available either as part of GIS software packages or on the internet. Alternatively, organisations may choose to develop their own set of appropriate tools for these purposes.

Spatial reference system

An organisation's data resources may use several different spatial reference systems. For example, one data resource may contain positions as latitudes and longitudes, whereas another may define positions using metres, with the distances referring to distances from a particular point on the earth's surface. It is not possible to view and manipulate these files together in a desktop GIS, without converting data resources to the same spatial reference system system. A DEF may specify the spatial reference system to which the data should be converted. There are tools available in GIS to change or define spatial reference systems. For example ArcToolbox™ contains a "Projections Toolset" which can:

- Define a dataset's spatial reference system information if it is missing;
- Modify a dataset's existing spatial reference system information, and;
- Convert a dataset from one spatial reference system into a different system.

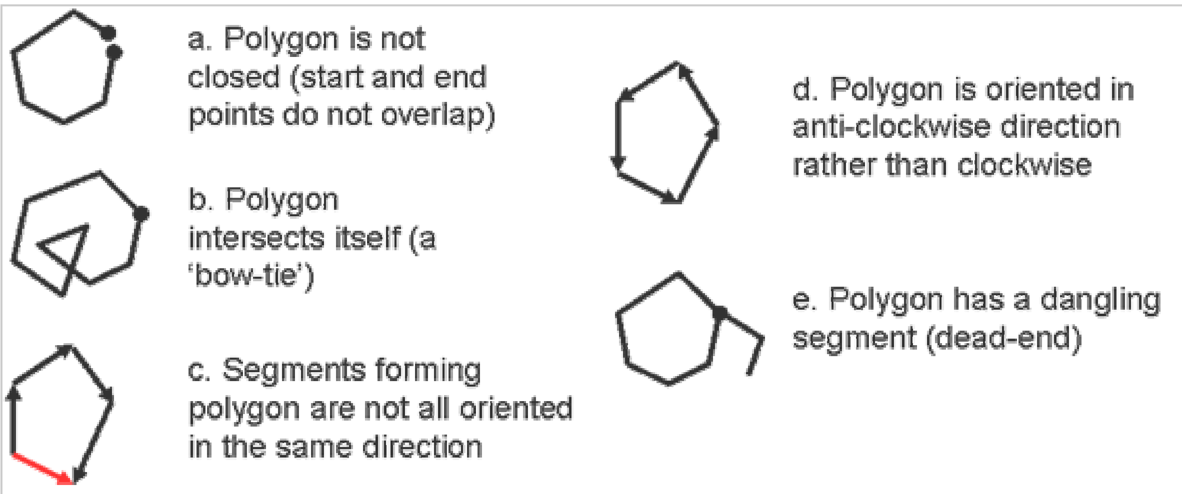
File names

It is extremely useful if data resources are named according to a file naming convention. This makes the cataloguing of and retrieval of data resources much easier. The naming convention could take many forms and will depend on what you find most practical. Aspects to consider are whether to have a file identifier as part of the name, whether to include text to make the file name more descriptive, or perhaps both. Using a file identifier as part of the file name will be invaluable if you plan to link the data resources to an external catalogue of metadata. The length of the file name should also be considered since some software still uses the old DOS 8/3 character format: for example, while MS Access uses long names as standard, is not able to link to a Dbase files (*.dbf) with a file name of longer than 8 characters. Therefore it is sensible to user identifiers for files which are at least unique to 8 characters. Remember to document the naming convention so that subsequent users of the system will be able to follow it. There are tools available on the Internet that can assist with naming large numbers of files according to a particular format. For example, MESH downloaded the tool *ReNamer* from www.den4b.com (written by Denis Koslov, © 2004-2006) and used it to change file names in batches.

Topology

In addition to defining a coordinate system, assigning file names and adding attributes, there is one final aspect which needs to be considered when collating vector data resources - topology. In GIS today, topology refers to the relationship between adjacent features. This may seem remote from seabed habitat mapping but it is essential to consider topology when collating map data. Topological rules assume that geographic features occur on a two-dimensional plane. Spatial features are then denoted by nodes (0-dimensional cells), edges (1-dimensional cells), or polygons (2-dimensional cells).

The topological rules used by GIS packages mean that certain functions require vector data resources to contain topologically correct (simple) features for these functions to operate successfully. For example, the tools in the Geoprocessing Wizard of ArcGIS™ (dissolve, merge, union, intersect) may fail if the input shapefiles have features with topological errors (often known as non-simple features). In shapefiles generated from seabed habitat mapping data, common topological problems are: features oriented in an anti-clockwise direction rather than clockwise; 'bow-ties' caused by self-intersecting features; and, dangling segments within features. The figure shows a set of simple diagrams illustrating non-simple features.



Illustrations of non-simple features according to ESRI™ topological rules for features.

Therefore, if you are collating shapefiles that you plan to analyse or edit using spatially analytical tools, it is important to check their topology and simplify any non-simple feature where possible.

Time will obviously be saved if shapefiles are checked in batches. For this purpose, MESH has developed a suite of tools for use in ArcGIS™ that can process shapefiles in batches:

- *Document shapefiles*: identifies shapefiles containing non-simple features;
- *Simplify shapefiles*: simplifies shapefiles containing non-simple features, and;
- *Dissolve shapefiles*: dissolves a batch of shapefiles based on an attribute specified by the user (useful for making boundary polygons).

Sometimes the *Simplify shapefiles* tool is unable to simplify all the features in a shapefile. In this case there is an additional set of tools that process the shapefiles one at a time to help trace the error:

- *Find non-simple features*: finds and simplifies non-simple features in a shapefile and deletes features with an empty geometry;
- *Split multipart features*: splits multipart features into individual features which retain the attributes of the original multipart polygon;
- *Remove interior rings*: removes interior rings from features which is useful for removing artefact slivers resulting from union operations, and;
- *Re-order shapefile*: a useful tool for visualising data which helps prevent larger features obscuring smaller ones by drawing the largest polygon first.

The **ArcGIS MESH Tools** are available for anyone to use but please note that neither the MESH Project nor JNCC offer any software support for these tools; they are used at your own risk. To date they have been used only in ArcGIS™ 8.2 and 8.3. Please keep back-up copies of all data before using the tools.

Links to other sections:

data archiving

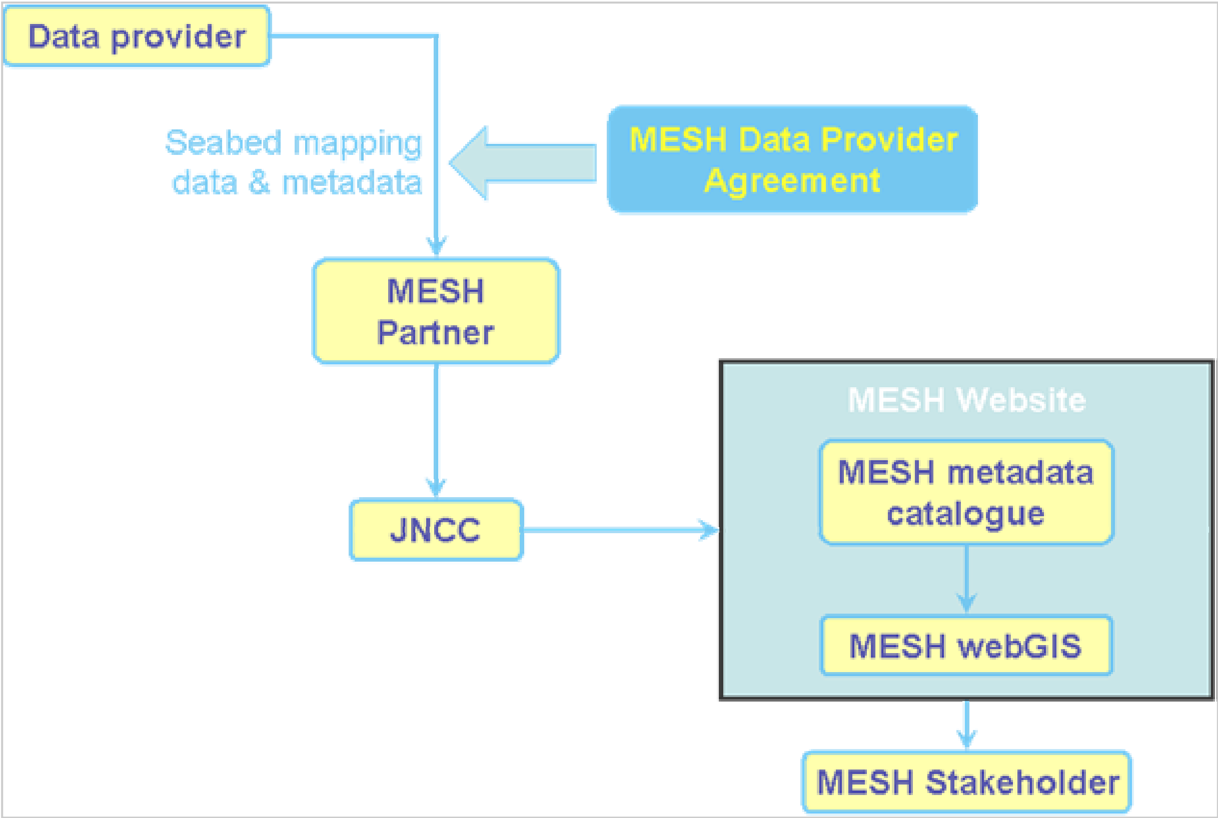
Links to websites:

http://www.den4b.com/

Data agreements

A data agreement is a formal agreement that sets out both the terms and conditions for use and dissemination of a data resource (as required by a data owner when their data are supplied to another organisation), *and* the expectations of the recipient in terms of the quality and validity of the collated data resources. The agreement is required to ensure both parties (i.e. the Data Provider and the Data Recipient) have a clear understanding of the basis upon which the data have been provided and upon which they can hold, use and disseminate those data. This is particularly important if data may be used to compile new habitat maps which could be disseminated to other parties.

The MESH Project has written a *Data Provider Agreement* which is a formal agreement between the MESH Partner, JNCC Support Co., and anyone providing material (i.e. data such as habitat maps) for use by the Partnership. The position of the agreement in the data flow process is shown in the figure. The MESH Data Provider Agreement (see *MESH Data Provider Agreement.doc* in the *Resources* section) is a formal agreement between a specified MESH Partner and anyone providing material (i.e. data such as habitat maps) for use by the MESH Partnership. The Agreement is required to ensure both parties (i.e. the data provider and the data receiver) have a clear understanding of the basis upon which data are provided and upon which we can hold, use and disseminate them.



The position of the MESH Data Provider Agreement in the flow of seabed mapping data and metadata in the MESH Project.

Converting maps

When marine habitat maps are made, mapping scientists chose mapping units which are best suited to the purpose of the map, perhaps to describe broadscale physical features or detailed biological information. The variety of reasons for mapping the seabed has resulted in an almost equal variety of mapping units used to make maps. In the context of marine habitat mapping these mapping units are called habitat classes. A defined set of habitat classes is known as a habitat classification scheme. The process of converting habitat classes from one classification to another has been called "**translation**" by the MESH Project. This section will explain the benefits and feasibility of translation, and the processes by which it can be undertaken. It focuses on translation to the EUNIS classification scheme (European University Information Systems: http//:eunis.org), because this is the common classification scheme used by the MESH project. When faced with an array of maps – often created for diverse purposes, and perhaps brought together by a data collation project – it is natural to want to use the maps to ask questions about the occurrence and extent of habitats that are of interest to you. Answering these questions is impossible without first converting maps to a common set of mapping units, or habitat classes. Translation is vital in marine habitat mapping to allow maps to be used to answer the widest range of possible questions.

Why should I translate maps?

Translation adds value to mapping studies previously undertaken. For example, a previously completed Environmental Impact Assessment (EIA) for a local port development may have produced a series of habitat maps to a local classification scheme. In effect, the maps represent a local inventory of what can be found within the study area. By translating these maps to a national or international classification scheme, this local inventory can be placed in a wider national or international context. Table 1 below indicates some typical scales at which mapping studies are undertaken, and the type of classification often used at each level.

Scale of mapping	Purpose of mapping study	Example classification scheme
Local	Environmental impact assessment e.g. habitat map produced as part of port development	Habitat classes used within a single local mapping study
Regional	Strategic Environmental Assessment	Habitat classes used for a suite of habitat maps across a region
National	National mapping study	National Marine Habitat Classification for Britain and Ireland
European/International	European mapping study (e.g. MESH)	EUNIS classification scheme or Annex I habitat types

A table showing the different scales of mapping studies and associated classification schemes.

This translation process need not be restricted to habitat maps but can be applied to other types of maps too. The British Geological Survey demonstrated this by translating their 1:250,000 series seabed sediment folk maps (a dataset containing no biological information) to a 'modified folk classification' map, equivalent to a high level in the EUNIS classification scheme, an important starting point for habitat mapping. Therefore, maps produced for one purpose may be used for another purpose with a relatively small amount of effort to translate them.

In addition to adding value to existing maps, translating maps to a common classification scheme can allow you to get a regional or international perspective from local mapping studies. For example, a collection of local mapping studies may have recorded the distribution of a nationally threatened habitat such as a seagrass bed. However, if the maps were produced using different local classification schemes, it becomes very difficult to compare maps within one country, and even more difficult to ask questions of maps between different countries. By relating these local studies to a national or international classification system, policy makers, marine environmental managers and stakeholders can review the distribution of a particular habitat from a national or international perspective.

The MESH partnership selected the EUNIS classification scheme (http//:www.eunis.org), a European scheme, as the common classification scheme to be used by the MESH project. The EUNIS classification has undergone a recent revision, and the MESH project was seen as a useful testing ground for the revised classification. In addition to EUNIS, Annex I[2], OSPAR[3] and UKBAP[4] habitat types were also identified as key classification types which would add value to the local and national mapping habitat studies.

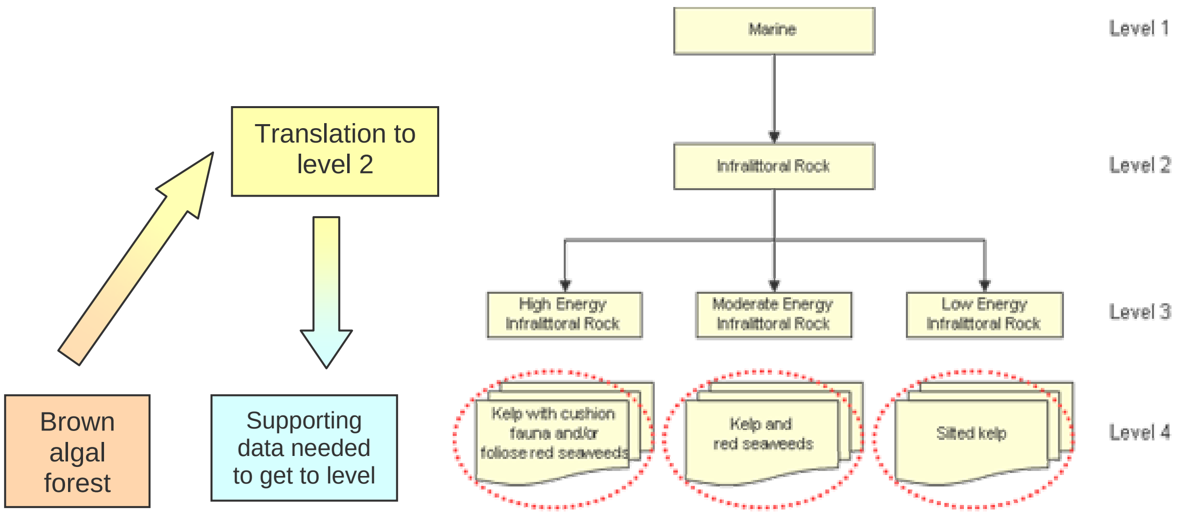
After reading this section detailing the benefits of translating your habitat maps to EUNIS and other classification types, the next question to address is whether your maps are suitable for translation.

Can I translate my map?

When considering whether to convert your map or maps to another classification scheme, the first question to answer is whether it is possible to translate them. Remember that some classification schemes will be inherently incompatible with other schemes. Incompatibility comes about largely as a result of the methods used to define the habitat classes. Habitat classes may have been defined using different parameters, with varying thresholds for each parameter. Therefore, it is recommended that a preliminary check of the habitat maps you wish to translate is carried out to assess their suitability. Examine the habitats identified in your map and compare them to those available in the target classification scheme. For example, in the diagram showing the correspondence between two classification schemes, the tan box on the left indicates a lifeform type from the map to be translated, approximately equivalent to level 4 of the EUNIS hierarchy: brown algal forest. This

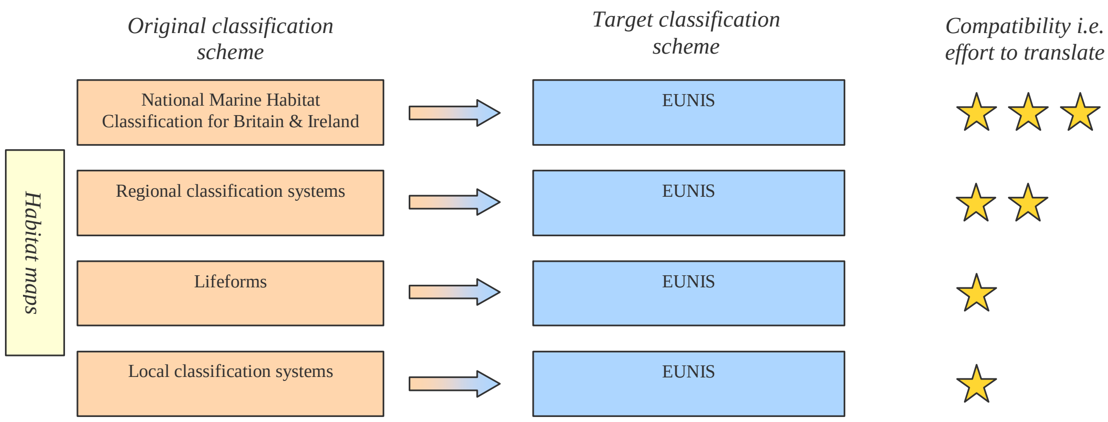
[2] Annex I habitats are those listed under the 1992 EC Habitats Directive.
[3] OSPAR Habitats refer to those habitats on the initial list of threatened and/or declining habitats which was adopted in 2003 and amended in 2004.
[3] UKBAP (UK Biodiversity Action Plan) habitats (United Kingdom only)

original habitat type can be translated to a high level within EUNIS (Level 2: infralittoral rock). To determine the habitat at a lower EUNIS level (Level 3/4), further supporting data such as wave exposure or tidal stream would be required to determine the type of infralittoral rock.



The correspondence between two classification schemes: lifeforms on the left and EUNIS on the right.

Where the original classification scheme and target classification scheme share a similar structure (hierarchy), the process of translation can be approached with relative ease. An example of this is the relationship between the National Marine Habitat Classification for Britain and Ireland[5] and the EUNIS[6] classification scheme. This is one of the examples given in the figure showing the compatibility between EUNIS and other classification schemes. A three star rating indicates that habitat classes at a particular level of the original classification scheme generally match those in the same level in the target classification, so minimum effort is needed.



The compatibility between original and target classification schemes.

A two star rating indicates that some only some may match, with others requiring more effort to reach the same level in the target classification when translated. One

[5] National Marine Habitat Classification for Britain and Ireland reference
[6] EUNIS reference

Close

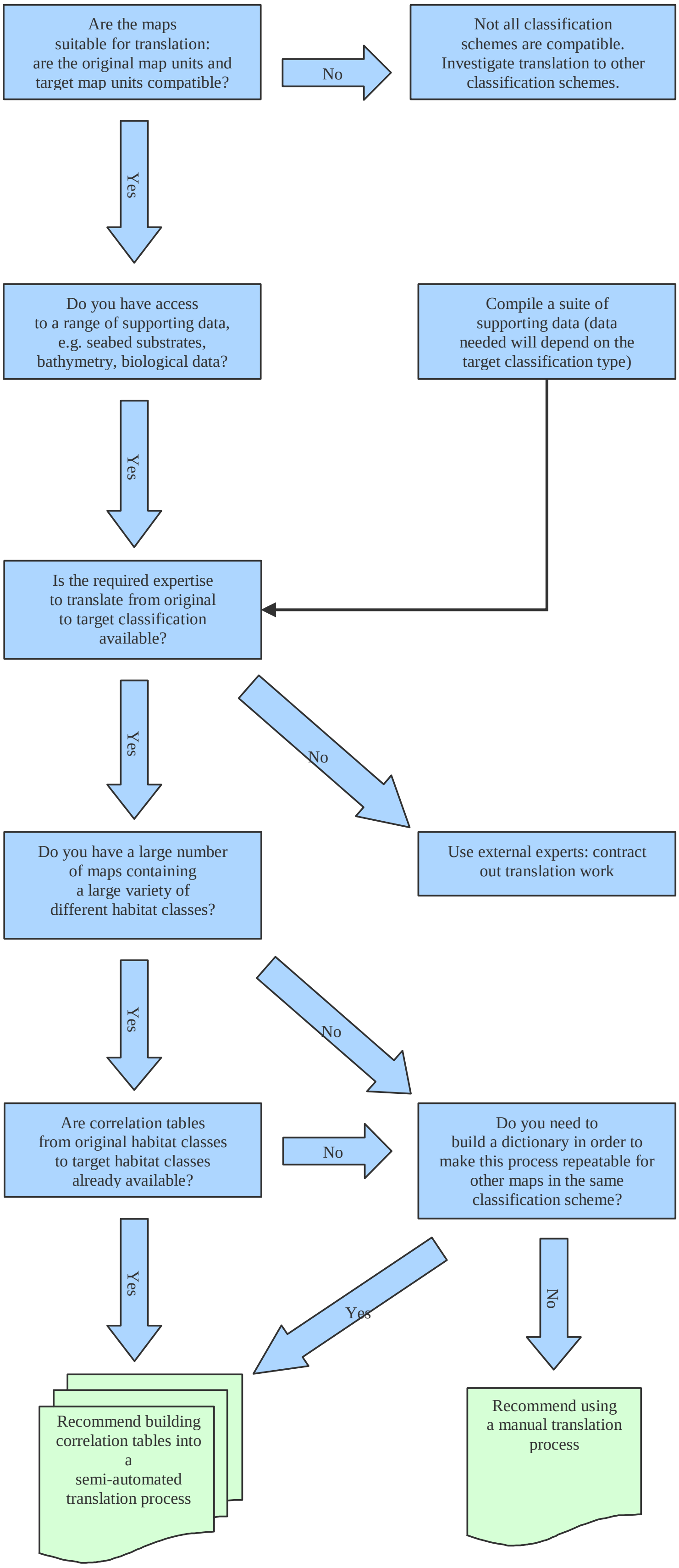
star indicates that very few, if any, of the habitat classes are likely to match and considerable effort will be required to translate them to the target classification scheme. In some cases, the two classification schemes may be incompatible and no translation possible. Be aware that a possible reason for this incompatibility is that the target classification scheme does not appropriately define habitats for the environment you are mapping. One outcome of translation is the identification of such gaps and the subsequent proposal of new habitat types. A system should be established to allow potential new habitat types to be recorded.

The translation process

Vector data formats are commonly used in marine habitat mapping, partly because of the flexibility they offer to the user to apply many attributes to a features. In the context of these vector data resources, translation means editing or adding to the attributes of a feature, such as a point, polygon or line. The essential attribute to add for each feature is the corresponding target habitat class. It is good practice to add other attributes such as the date and method of translation as well as any comments; these additional attributes form an 'audit trail', allowing the choices made in translating the map to be traced. The translation process will vary depending on the number of maps to be translated, but it can be split into two stages.

The first stage is the process of correlating habitat classes from the original classification to the target classification. This can be done using the 'expert eye' approach, where an individual examines each original habitat class and selects an appropriate matching habitat class from the target classification scheme. This is potentially a very time-consuming method process, but it is manageable if only a small number of habitat maps are being translated. For larger numbers of maps using the same classification scheme, it is worthwhile to develop a correlation table between the original and target classification, or if possible to use an existing correlation table. This approach will also involve an 'expert-eye' to build the correlation table, but when this has been built it will be useful for subsequent translations. Unfortunately, neither of these two approaches is helpful when you have a large number of maps to translate which all use different classification schemes. In this situation, multiple correlation tables must be built by inspection of the original habitat classes and the target habitat classes, making up a translation dictionary.

In the second stage, the habitat map data files are updated with the information from the first stage of the translation process, either from the expert eye interpretation or from a correlation table. The data files may be edited manually, although as a guide, edits to a habitat map data file of over 100 polygons would be best made an alternative method such as database queries. Where large numbers of maps are being translated an automated routine will facilitate the update of the map attributes. Some partners in the MESH project employed this automated approach, using bespoke MS Access modules to add the required attributes to the data files. The questions that need to be answered before the translation approach is decided upon are shown in the decision tree. More detailed information on these two stages can be found in *MESH Translation Worked Example.doc* in the *Resources* section of the MESH Guide.



Decision tree providing guidance on which translation approach to select.

Close

Using supporting data

When translating between an original and target classification scheme, it is highly recommended that supporting data are used. An original habitat class may translate to several alternative habitats in the target classification scheme, depending on the exact environment in which the habitat is found, also known as the 'habitat envelope'. Under these circumstances, supporting data are crucial in ensuring that the correct target class is selected. For instance, the MNCR 97.06 classification of 'Littoral gravels and sands' translates either to EUNIS A2.1 or A2.2, depending on whether the substrate is sand or coarse sediment. Suggested supporting datasets include:

- *Bathymetry*: to distinguish between infralittoral and circalittoral habitats
- *Light attenuation*: to refine the bathymetry and more accurately define photic and aphotic zones depending on the light reaching the seabed at certain depths
- *Seabed substrates*: to distinguish between habitat classes which are have the same definition apart form the substrate type
- *Wave exposur*e: to distinguish between energy regimes for rock communities (EUNIS level 3). These data are, particularly useful where detailed biological information is provided in the original habitat description but with no indication of the energy level of the environment
- *Salinity*: to distinguish between possible habitat classes useful when translating estuarine habitat maps
- *Tidal currents*: to distinguish rock communities in tide-swept locations

The type of supporting data used may vary with the habitat map being translated, but one of the most useful types of information will be benthic point sample data. For example, sample collected by direct observations of the seabed (diver or shore survey) or remote observations from grab sampling, dredges or video (drop down/towed/ROV). This information type is particularly valuable if the samples are interpreted into habitat classes belonging to the target classification scheme: this can provide an indication to the translator of the habitats recorded in the vicinity. As part of the MESH project, a Habitat Matching Program has been developed. This program can match imported physical and biological sample data to EUNIS classes (see the *Habitat Matching Program* in *How do I make my map?*). Point sample data can be spatially joined to a habitat map in a GIS so that each habitat polygon is linked to the validation samples which fall within it). The results of a cross-tab query in MS Access are shown in the validation matrix table.

Original Habitat	SS.SCS.CCS.MedLumVen	SS.SCS.ICS.Glap	SS.SMp.KSwSS.LsacR.Sa	SS.SMp.SSgr.Zmar	SS.SMu.IsaMu.MelMagThy	SS.Ssa.ImuSa.EcorEns	CR.FCR.FouFa	Translated EUNIS code
Gravelly sand		5	2			2		A5.13
High impacted static dredging area	1	2	2	1	3			A5.13
High impacted static+trailing dredging area	1	1	1	3				A5.12
High impacted trailing dredging area	1	3				1		A5.12
Low impacted trailing dredging area	1	1	1					A5.12
Sand over gravel	1			2	1			A5.12
Sandy gravel	2	2	1	2	2			A5.12
Wreck							1	A4.75

A validation matrix showing original habitat class on the left versus the habitat class of point sample data at the top. A column has been added indicating the target translated habitat.

While supporting datasets can assist in making translation decisions to select the appropriate class in the target classification scheme, these datasets should *not* be used to reinterpret the original data. For example, a group of polygons classed as 'sublittoral mud' in the original habitat map should not be reclassified to 'sublittoral sand' (A5), even when the majority of supplementary information indicates that sublittoral sand is present; the person producing the map may have had overriding evidence not available to the translator indicating that 'sublittoral mud' was the correct class to map. However, in these cases, a note should be made fielding the attributes of the data file indicating that, from the information available to the translator, there is uncertainty surrounding the original habitat class.

Translation relationships

When translating between an original class and target class, it is important that the relationship between these two classes is recorded. This can be examined by users of the translated maps to give an indication of how accurate the translation is likely to be, i.e. how well the target class represents what was actually mapped originally. The relationship between the original and target class can be simply expressed as a symbol, such as those included in the table of example symbols. For example, when the original class and target class share a one-to-one relationship, then you can be sure that the correct target class has been selected in the translation. However, if they share a one-to-many relationship, then there is a possibility that the incorrect target class has been selected.

Example symbols used to describe the relationship between two classification schemes.

Habitat in original classification	Relationship symbol	Habitat in target classification	Explanation
X	=	Y	Habitat X is same as Habitat Y: the habitat classes have a one-to-one relationship.
X	~	Y	Habitat X is nearly the same as Habitat Y.
X	>	Y	Habitat Y is contained within Habitat X (i.e. X has a broader definition than Y). This could be referred to as a one-to-many relationship.
X	<	Y	Habitat X is contained within Habitat Y (i.e. X has a narrower definition than Y). This could be referred to as a many-to-one relationship.
X	#	Y	The definition of Habitat X partially overlaps with that of Habitat Y.

When translating to hierarchical classifications in particular, a key factor affecting the translation relationship will be the level of the hierarchy in the target classification to which you are translating. When translating to a very high level in the hierarchy, there may be a high degree of confidence, (you are sure the polygon can be described as sublittoral sediments) but your confidence level reduces as you go down the hierarchy to more detailed levels (you are not sure whether the area best described as sublittoral mixed sediments or sublittoral coarse sediments). It may be very easy to translate from the original to target classification at high levels in the hierarchy, with little or no need for supporting data, but the resulting map would be of limited use. The translated map would only show the distribution of broad habitat classes, and much of the information captured in the original map would be lost. When translating to lower levels in the target hierarchy, it is likely that supporting data will be required to produce a product with an acceptable level of translation confidence; although this will require additional resources, it will result in a more robust map containing more information. It is the person completing the translation who should judge the appropriate level in the target classification. Using an attribute in the translated data file to record comments of the map translator is essential.

Links to websites

http://eunis.org/

http://www.eunis.org

Combining maps

When maps produced by individual habitat mapping studies are brought together, there are likely to be areas where they overlap. Overlapping maps are not a problem as such; however, the maps have probably been produced at different scales for different purposes and using different methods. Even after translation to a common classification scheme, it is anticipated that maps will not always concur in areas of overlap. Furthermore, maps are produced to be viewed at a specific scale, and combining them into a single electronic map view (for example in a GIS or an interactive mapping website) can allow the user to zoom freely and view the maps at any scale. This gives the illusion of scale-free maps, unlike the case of printed maps where the size a feature that can be distinguished on a map depends on the paper size used. This section proposes some solutions to the problems caused by combining electronic maps, particularly problems resulting from overlapping maps and flexible viewing scales. Maps are designed to visually convey a message to the map user, and the saying ‘a picture tells a thousand words’ is one often cited by map makers. How clearly those ‘thousand words’ are spoken after the map has been combined with others is dependant on successfully addressing challenges caused by this amalgamation.

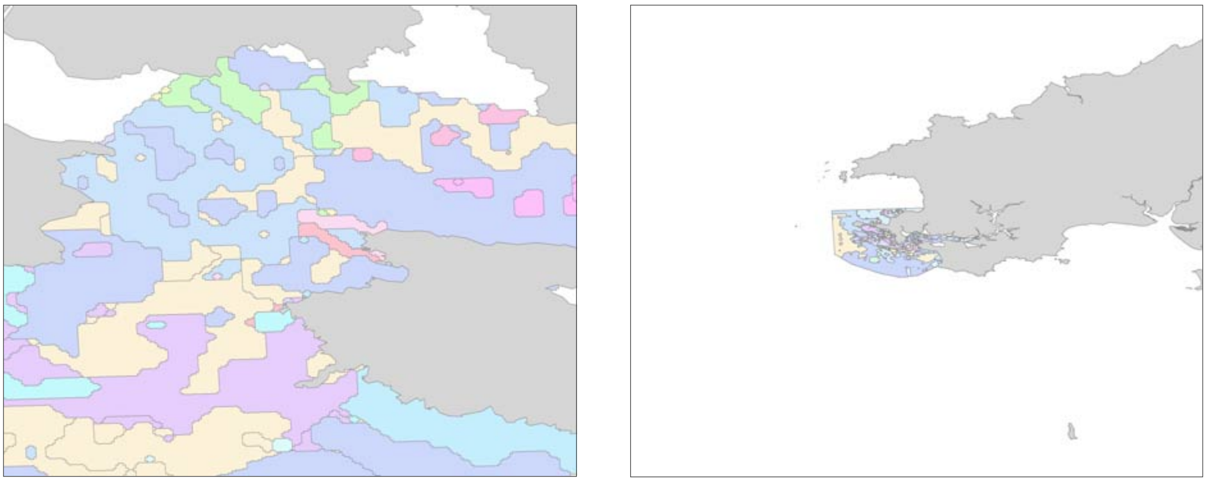
Overlapping maps

Where features from different mapping studies overlap geographically but their attributes do not match, overlaps can be addressed at a map or feature level. At a map level, the decision on which overlapping map should be taken in preference to another can be based on information provided in the metadata describing the study, particularly any assessment of confidence. For example, consider a situation in which two overlapping surveys contained conflicting information, where one map was produced using high quality multibeam echo sounder, side scan sonar and dense ground-truth sampling (a ‘high confidence’ map), while the other map was produced using interpolated ground-truth samples (a ‘low confidence’ map). The former map would take precedence over the latter on the basis of the confidence assessment. The part of the map with the lower confidence that overlaps the map with higher confidence could be removed, leaving a single layer from the two separate mapping studies.

The alternative option is to assess overlapping features; in habitat mapping studies these features are referred to as polygons. Overall this approach is far more detailed than the map level approach suggested above. It requires extremely detailed metadata describing each polygon, effectively a standard confidence rating for each polygon across multiple maps, which is unrealistic where maps have been collated from diverse sources, probably using a wide range of different methods. For example the relationship between the original classification scheme and the target classification scheme should be taken into account at the polygon level since some polygons in the map may contain original habitat classes which are well-matched to the target codes, whereas others are poorly matched and hence would be of lower priority when merging features to create a single layer in one classification scheme. In summary, this approach would only be feasible if there are a small number of overlapping maps in an area about which you have sufficient expertise to make decisions about which polygons best reflect the seabed habitats in that location.

Maps for different scales

When viewing fine-scale maps in the dynamic environment of a GIS package, the map rapidly becomes overloaded with information as you zoom out to broader scales, unless some form of summarising of the data is performed. A good example of data summarising at increasing scales can be seen when looking at road maps. Although a 1:25,000 Ordnance Survey map can show the same area as a 1:190,000 road atlas, the former has been generalised, so that in the latter, only the key information such as major routes can be seen. In the same way, detailed habitat maps require some degree of generalisation, particularly when looking at a set of fine-scale maps in a broader context. The example maps at different viewing scales show that, using GIS, as you zoom out from a very detailed fine-scale habitat map, it becomes very difficult to distinguish individual features, and the map becomes unclear so that information is not conveyed; general trends in habitat distribution may be lost because of this cluttered view.

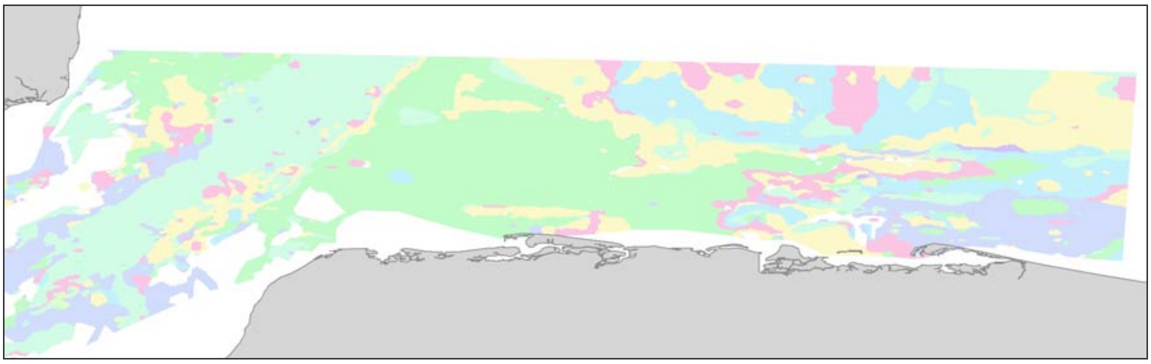


An example of different viewing scales for the same marine habitat map : on the left is a map at scale 1:50,000, and on the right is the same map at scale 1:1,000,000.

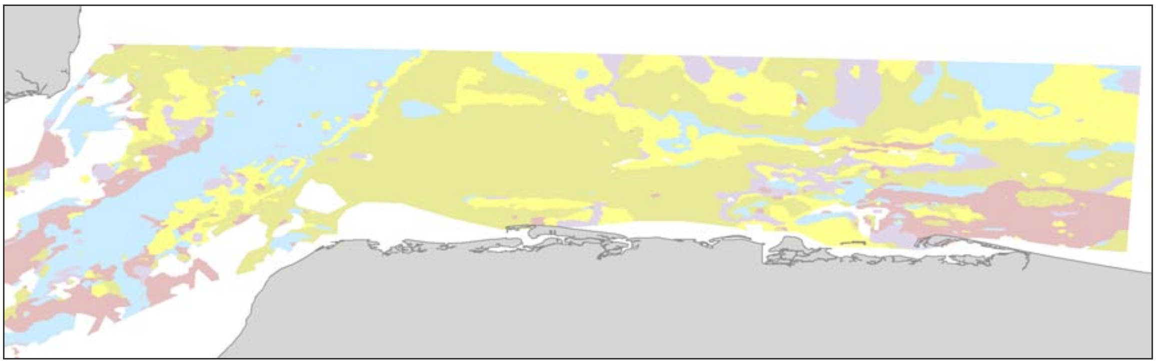
Cartographic generalisation is the process adapting the information shown by a map to suit the scale at which it will be displayed. There are a several methods of generalisation which are relevant to enhancing the clarity when viewing seabed habitat maps in GIS. For example, *smoothing* can reduce the angularity of features such as habitat patches by removing vertices. *Enhancement* is used to highlight specific details of the map, perhaps Annex 1 features occurring in a seabed habitat map. *Combination* of features can be carried out when their separation is not relevant to the map scale. In seabed habitat mapping this can be applied by summarising features up the classification hierarchy; this method is examined in more detail in the following section. Many processes of cartographic generalisation have now been automated in GIS packages. Automated raster filtering tools are discussed in more detail below.

Summarising habitat classes

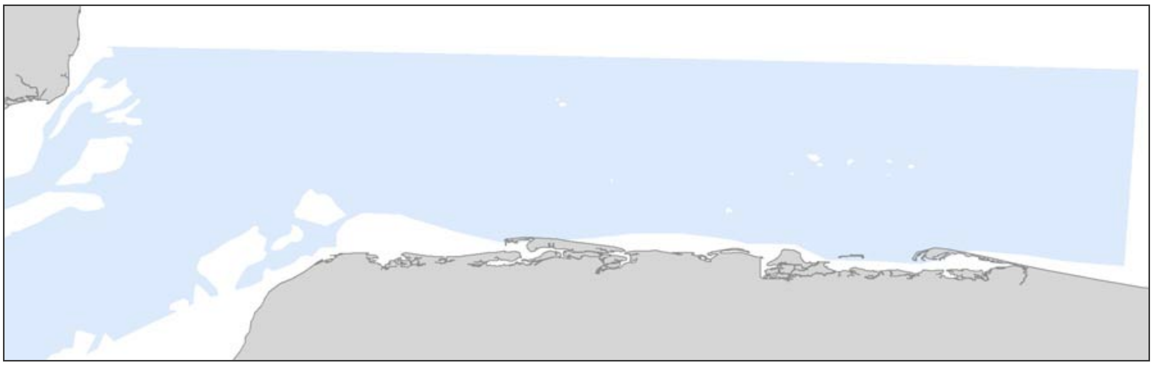
This method can only be used if your maps are classified according to a hierarchical classification scheme, or can be converted into such a classification scheme. A hierarchical classification scheme generally relies on the premise that as you move up the hierarchy, the definitions of classes become broader.



Habitat map at EUNIS level 5: for example Echinocardium cordatum *and* Ensis *spp. in lower shore and shallow sublittoral slightly muddy fine sand*



Generalised to EUNIS level 3: Polygons are classed as one of five types of sublittoral sediment, such as Sublittoral coarse sediment, sublittoral sand etc



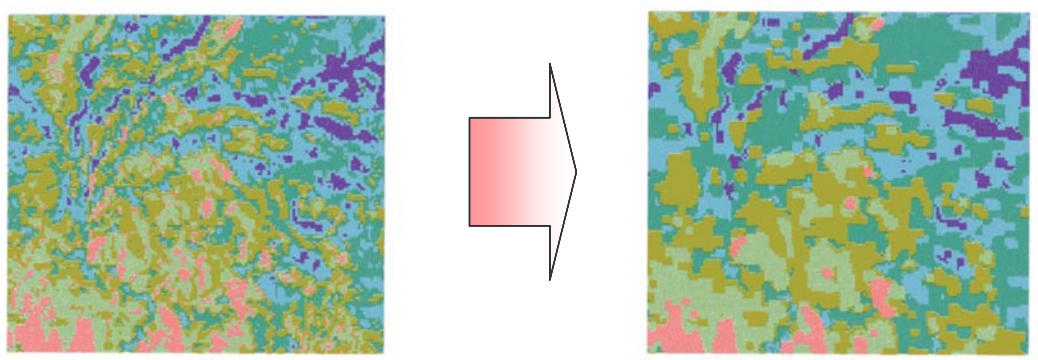
Generalised to EUNIS level 2: All polygons are classed as sublittoral sediment

An example of how generalisation up the EUNIS hierarchy could work, scale 1:500,000

An example of what happens as you move up the EUNIS hierarchy is shown as a top-to-bottom sequence of maps. There is little difference in the amount of information contained in the map when comparing EUNIS level 5 and 3, probably because only a handful of polygons had been classified to level 5. When the map is summarised to EUNIS level 2, the almost all the information that could be useful at this scale is lost. However, EUNIS level 2 generalisations may be appropriate at broader scales than 1:50,000 shown here. An improvement in clarity is largely dependent upon adjacent polygons coming from the same ‘part’ of the classification hierarchy, such as ‘sublittoral sediment; in the example maps. This is not always the case, and can result in the retention of detailed habitat polygons even at high levels of the classification scheme. Hence a broadscale view of a map in a heterogeneous area could remain unclear even after summarising up the classification hierarchy.

Automated raster filtering

Raster filtering tools available in many proprietary GIS software packages provide a method of cartographic generalisation. Raster datasets containing more information than you require can be reduced in detail using these tools. The example here was applied to a satellite image using the ESRI ArcGIS Spatial Analyst extension. For more information about the range of tools available, see the ESRI website [http//:www.esri.com].

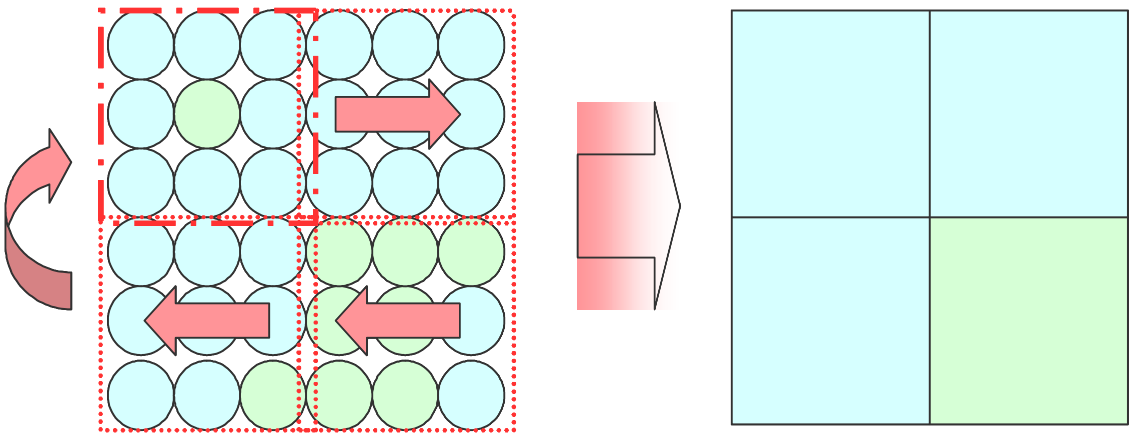


The base classification from a satellite image

Effect of MajorityFilter applied to the output from Nibble

An example of cartographic generalisation of a satellite image using ESRI Spatial Analyst

One advantage of using such cartographic generalisation rather than simply summarising habitat classes at higher levels of the classification hierarchy, you are able to retain some instances of rare protected habitats. These usually occur at the detailed level of a classification hierarchy since they are often species specific. For example *Sabellaria* reefs (EUNIS code A5.611) or *Ostrea edulis* beds (EUNIS code A5.435) may be used as biodiversity indicators.



= A5.443 = A5.611 (*Sabellaria* reef)

An example of a generalisation procedure where the cells that fall within a defined search area (red box) are examined, the modal or majority habitat is identified and then assigned to all the other cells within the defined area.

From the generic diagram showing a generalisation procedure, notice that although the smaller area of *Sabellaria* reef is 'lost' during the process, the larger area of *Sabellaria* at the bottom right is retained, ensuring that this habitat is still represented on the generalised map. It is also worthwhile noting that if the habitats in the diagram had been summarised up the EUNIS hierarchy to level 3 or higher, the blue cells would be labelled A5.4 (sublittoral mixed sediment) and the green cells as A5.6 (sublittoral biogenic reef); information about the distribution of *Sabellaria* would no longer be available in this generalised map. Of course there are difficulties associated with using automated routines for generalisation; often it will be necessary to develop specific methods appropriate for your maps in order to preserve the correct level of detail.

Links to websites:

http://www.esri.com

Sharing maps on the internet

With the rapid development of computer technology over the past decade, the capability to rapidly access and process data and information has significantly changed our approach to marine environmental research and management. It is now possible to quickly search for information across multiple sources via the internet, often with the additional capability to download data (physically for local storage, or dynamically) for display and analysis on local machines. Sharing maps on the internet has several significant advantages, both for the organisation that owns the maps, and users of the maps: sharing information can save resources by raising awareness about where data are already available so that additional survey effort is not required; data owners can get publicity for the data they hold; maps can be accessed by staff while they are away from the office intranet or network. With these advantages come some problems: with the escalating number of mapping websites there is often confusion in the user community about where to look for marine data. Making maps available online invites non-expert end-users to use and interpret maps for any purpose, without having to consult habitat specialists or consider the survey methodologies used. The once obvious necessity to communicate with map makers is no longer felt. Before deciding to build a mapping website for your organisation's mapping data, it is essential to verify whether resources could be saved by contributing your data to an existing mapping website.

Desktop geographic information system (GIS) technology allied to emerging international data standards now enables complex visualisations of spatial data, often using data located on both local machines and remote internet servers. This section describes how it is possible to make maps available on the internet, whether by contributing to an existing mapping website or by building a mapping website. The second part of the section gives an outline of how it is possible to combine your maps with other online maps.

Contributing to an existing mapping website

There are numerous projects and organisations that currently support internet mapping. If you have limited resources but want to publicise your mapping data, perhaps the simplest option available to you is to contribute your maps to an existing mapping website. This will certainly save time and money otherwise needed to build your own internet mapping solution, but you will sacrifice a certain amount of control about how the data will appear online. One of the most challenging parts of the process is to first disentangle a complex web of local, national and international websites dedicated to display of marine mapping data, in order to decide which is most appropriate for your data. The decision will depend on practical issues such as whether existing websites are willing to receive data from other organisations, what types of data they specialise in, and what formats they require. When contributing to existing mapping websites, the organisations responsible for the mapping data may ask you to supply data in a particular format. For example, habitat maps contributed to the *MESH webGIS* are supplied in a Data Exchange Format (DEF) to make the process of compiling maps more efficient. Websites will also require you to submit metadata [link to glossary] to describe the data you are supplying. You should also consider the profile and longevity of potential websites. How well-known are existing websites in the marine mapping community? Do they have plans for maintenance into the future?

Building a mapping website

Internet mapping can be delivered through a two main routes: to build a software package specifically for your purpose; or to customise a software development package to meet your needs. Examples of both options can be found throughout the internet. It is more common, and potentially more economical, to use proprietary development packages such as ESRI ArcIMS™. More recently, 'open source' software such as MapServer (http://mapserver.gis.umn.edu) has appeared that has the advantage of not requiring a commercial licence to run the application on a web server. Unless the required mapping functions are extremely complex in terms of the range of functions currently offered by various packages, the development of bespoke software is unlikely to be justified. Alternative development environments will have advantages and disadvantages, but the basic choice is between:

- Using a proprietary package, such as ArcIMS, which has a large pool of experienced developers but accepting that there will be a licence fee.
- Using an open source package, such as MapServer, that may have a smaller pool of experienced developers but which does not require a licence fee to be paid.

MESH chose the second of these options, and more information about the MESH webGIS can be found in the worked example *MESH webGIS user guide.doc* in the *Resources* section of the MESH Guide.

How do I combine my maps with others on the internet?

Whilst users can query and visualise the data on the internet, they will often wish to view their own data in conjunction with the data resources held by other organisations. One potential method for giving access to data resources is via a remote internet server where users can add data, for example from a mapping website, directly to their desktop GIS rather than having to download a copy to their local machine. There are clear attractions to this option from a data management perspective since users will always access the most up-to-date version of the data. In simple terms, the aim is to move from data 'hoards' to connected sets of data. A disadvantage of such direct access is the requirement to be connected to the internet to view the data.

Geospatial interoperability

"Geospatial Interoperability is the ability for two different software systems to interact with geospatial information. Interoperability between heterogeneous computer systems is essential to providing geospatial data, maps, cartographic and decision support services, and analytical functions. Geospatial interoperability is dependent on voluntary, consensus-based standards. These geospatial standards are essential to advancing data access and collaborations in e-Government, natural hazards, weather and climate, exploration, and global earth observation."[7]

Geospatial standards have been established by the OpenGIS Consortium (http//:www.opengeospatial.org) in a series of specification documents. OpenGIS®

[7] National Aeronautics and Space Administration, Geospatial Interoperability Office (2005) Geospatial Interoperability Return on Investment Study Report. [http://gio.gsfc.nasa.gov/docs/ROI%20Study.pdf]

Specifications are technical documents used by software engineers to build support for interoperability into their products and services. End users can take advantage of products that include these specifications to publish and access geospatial information. Ideally, when specifications are implemented by two different software engineers working independently, the resulting components will work together without further debugging. Specifications are freely available and implemented voluntarily; the aim is for transparency based on cooperation.

In particular the specifications for Web Services are relevant users interested in combining their maps with others on the internet. A Web Service is any software which makes itself available over the Internet and using standard XML [link to glossary]. Web Map Service (WMS) and Web Feature Service (WFS) are examples of Web Services potentially of use to members of the marine mapping community. For example, WMS defines how to request and provide a map as an image or set of features, and how to get and provide information about the content of a map (such as the value of a feature at a location). WMS returns an image of the map from a mapping server, and is more widely available than WFS, where actual coordinates of features are returned and plotted locally. WMS has some considerable advantages over WFS:

- Many more third party applications can consume WMS than WFS
- WMS requires lower bandwidth than WFS (often very significantly)
- WMS protects data to a degree because only an image is downloaded; the actual coordinates of the features are not available
- The implementation of WMS in the main GIS packages is more stable than that for WFS
- Attributes of features can still be displayed using WMS services, although spatial queries cannot be carried out

However, some advantages of WFS over WMS are:

- WFS is vector based which allows spatial queries to be carried out on the features
- Digitisation (tracing) of the feature boundaries can take place

In addition to the options of WMS and WFS, developers of mapping websites can set up the software to act either as a server (serving data to local GIS systems) or as a client (where one of the available layers is consumed by another server on a different system). Developers should consider whether they want to act as a server or client, or both.

Links to websites:

http://mapserver.gis.umn.edu/

http://www.opengeospatial.org/

Glossary terms

ArcCatalog™: ArcCatalog™ is an application used by ESRI's ArcGIS, for managing spatial data holdings and for recording, viewing, and managing metadata.

ArcToolbox™: one of the applications comprising the ESRI™ desktop GIS package (together with ArcMap™ and ArcCatalog™).

Attribute: in the context of vector data resources, attributes define the properties of data fields associated with features within a data file, and consist of a name and value. For example, a feature in a vector shapefile may have the attribute of 'Habitat', where the values are any text entry taken from the EUNIS classification scheme, e.g. A1.23.

Attribute table: an attribute table is a GIS data file consisting of attributes held as separate data fields (for example, identifier, feature name, date, time, analyst name).

DEF: A Data Exchange Format (DEF) defines the characteristics of data to be exchanged between parties.

Discovery metadata: these should provide the necessary information to describe the data sufficiently to enable the user to find the data of interest (i.e. to answer the 'who? what? where? and when? questions). The term discovery metadata refers to a high level set of **metadata elements**.

ESRI Shapefile: The proprietary geospatial vector data format used by ESRI™ for their GIS software and other software products. Shapefiles spatially describe points, polygons and polylines. The term shapefile is generally used to mean to a collection of files with '.shp', '.shx', '.dbf', and other extensions on a common prefix name (i.e., 'habitat.*'). The actual shapefile relates specifically to files with the '.shp' extension; this file alone is incomplete for dissemination, as it depends on the other supporting files.

GIS: A Geographic Information System is a computer system designed to allow users to collect, manage, and analyse large volumes of spatially referenced and associated attribute data.

HTML: Hypertext Markup Language is a ubiquitous markup language used for the creation of web pages. A markup language combines text and extra information about the text.

Interoperability: the capability to communicate, execute programs, or transfer data among various functional units in a manner that requires the user to have little or no knowledge of the unique characteristics of those units.

Metadata: data about data, for example giving information about the characteristics and provenance of the data.

Metadata element: one of the pieces of information recorded in a metadata record. For example, the title of a data resource can be a metadata element.

Metadata standard: a set of metadata elements. Metadata standards are usually defined by official standards organisations, but they can also be defined by an organisation or project for a specific purpose.

Topology: in GIS today, topology refers to the relationship between adjacent features.

XML: Extensible Markup Language (XML) files are often used for exchanging information, both on and off the Web. Like HTML (Hypertext Markup Language) files, XML files use start and end tags to format their content. However, XML tags define the structure of elements in a document, whereas HTML tags define how elements should look. XML is extensible because you can extend it by adding your own tags.